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ENVIRONMENTAL CONTROL SEMINAR PROCEEDINGS

ROTTERDAM WARSAW BUCHAREST

May 25-June 4, 1971

U.S. DEPARTMENT OF COMMERCE
Maurice H. Stans, Secretary

BUREAU OF INTERNATIONAL COMMERCE
Harold B. Scott, Director

September
1971

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FOREWORD

This publication contains the papers presented during a series of seminars on water and air pollution controls conducted in Rotterdam, The Netherlands; Warsaw, Poland; and Bucharest, Romania, May 24-June 4, 1971. The United States portion of the seminar was also presented in Prague, Czechoslovakia, where the host government elected not to include papers by local experts.

The seminars were presented as a part of the Trade Missions program of the Bureau of International Commerce, and the presentation in The Netherlands coincided with the visit of a U.S. Specialized Trade Mission consisting of eight U.S. businessmen engaged in the pollution control industries.

The United States portion of the seminars was organized by Dr. Daniel A. Okun and Professor Arthur C. Stern, University of North Carolina, and consisted of three officials of the United States Government, three university professors, three businessmen and one official from the State of Pennsylvania.

Overall planning and organization of the seminars centered in the Trade Missions Division, Robert Wilbourn, Director, and the Embassies in The Hague, Warsaw, Bucharest and Prague. Compilation of this publication was done by the Trade Missions Division. Honorable Sidney R. Galler, Deputy Assistant Secretary of Commerce for Environmental Affairs served as Seminar Director.

Harold B. Scott
Director
Bureau of International Commerce

PREFACE

These proceedings incorporate the papers presented at a series of Seminars on Environmental Control, with particular emphasis on technology and management of water and air pollution control, conducted in Rotterdam, Warsaw, Prague, and Bucharest under the auspices of the U.S. Department of Commerce. Originally conceived for Rotterdam by the Honorable J. William Middendorf, U.S. Ambassador to The Netherlands, the Seminars were then extended to the three other venues. The editors were asked to organize U.S. participation in these Seminars, while Mr. Merritt Freeman of the Department of Commerce, together with staff of the U.S. Embassies in the several countries, arranged for participation by the local professional organizations and experts. Special recognition must go to our Dutch, Polish and Romanian colleagues who shared the programs for the Seminars with us. In Prague, there were no formal presentations by the Czechs, although we are most appreciative of the contributions by Professors V. Madera and J. Smolik who served as moderators of the water pollution and air pollution control seminars respectively.

While the papers present something of the essence of the problems and their solutions in the countries represented in these Seminars, the full value of the Seminars could only be captured by those who participated in the vigorous and significant discussions during the informal gatherings between formal sessions and following them.

Urbanization and industrialization create much the same problems in all societies, and we all have much to learn from each other if we are to resolve these problems expeditiously and economically. The new hardware developed in the United States can be extremely helpful in other countries, while some of the regulatory procedures and incentives developed in Europe might well be emulated in the United States. Such seminars as these provide an excellent initiative for the generation of exchanges among professionals in all countries.

Note should be made of the proceedings of a similar Seminar held in Bangkok in January, 1970, also under the auspices of the U.S. Department of Commerce, with a Proceedings "Water Supply and Sanitation in Developing Countries," edited by Pescod and Okun and published by the Asian Institute of Technology in Bangkok.

The editors hope that these Seminars and the Proceedings will help stimulate further exchanges in the future.

Daniel A. Okun
Arthur C. Stern
Chapel Hill, North Carolina
July, 1971

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ENVIRONMENTAL MANAGEMENT

THE DEDICATION TO ENVIRONMENTAL MANAGEMENT

By J. William Middendorf

U. S. Ambassador to the Netherlands

These seminars provide a forum for many of the leading experts of the Netherlands, of the United States, of Belgium, Germany and other countries, in a field which seems destined to be one of the most dramatic of the decade of the 70's. All--whether they represent government, science or industry--must feel a deep sense of privilege. They are in the forefront of an effort to assure for generations to come the most essential of all commodities--the quality of our environment. They are in the forefront of an effort which must succeed, and which will surely succeed.

As we all know, the question of the effect of human activities on the environment did not receive enough attention for too long a time. The development of industry supplied good jobs and the good things of life to hundreds of millions of persons. But it inevitably affected the air and water around us. The motor car offered essential transportation for many millions--but also at an environmental cost.

It is only in the most recent years that people and governments and industry all over the world have fully realized the need to preserve and restore clean air and clean water. Now we must act on that realization. In all countries urgent programs are going forward. They involve legislation, sizeable research grants for scientific institutions, and large industrial projects. When such massive effort is concentrated on a problem there is reason for confidence that solutions will be found. In our striving for solutions there are, it seems to me, a number of factors which we should keep in mind. One of these is the need to resist pressures for quick solutions, and to exercise great care that the solution which we select for an individual pollution problem does not create an equal or worse problem of a different sort.

I have in mind, as an example, discussions now taking place in the United States and in other countries concerning detergents which contain phosphates. Some persons have expressed the view that such detergents cause eutrophication in lakes, ponds and other bodies of still water. As a result much pressure has developed to restrict, or even ban, the use of such detergents, and to substitute soap and non-phosphate detergents.

There appears to be some very interesting contrary considerations, however. Some experts believe that elimination of phosphates from detergents would do little to solve the eutrophication problem. Moreover, they note that, if soap is used as a substitute, modern fabrics will not last, and that soap and its ingredients would soon be in very short supply. Some other known substitutes, on the other hand, pose serious accident hazards, especially to children. To achieve a measure of environmental improvement at such a risk is obviously not worthwhile.

Another factor which deserves our careful attention is the cost and the effectiveness of our effort. Improvement of our environment is essential; it is possible; but it is not free of charge. A better environment will come about as a result of a large expenditure by industries in their efforts to clean up production processes. It will come about after large budgetary expenditures by governments. Regardless of the source of the funds, a great part of the burden will ultimately be borne by the individual user of the products of our society, and by the individual taxpayer.

We must take care that these funds are spent economically and wisely. The solutions which we select should be based on the most painstaking research and the most effective modern technology. The solutions should safeguard the quality of our air and water. They should also, however, safeguard the existence of our industries, the jobs of our workers, and to the extent possible the living standards of our people. Solutions which are so costly or so burdensome as to endanger the ability of our industries to remain in operation are not worthwhile.

The need for international cooperation in the effort to improve our environment is clear. Environmental problems know no boundaries. Neither should the work of governments, scientists and industry to solve these problems. The United States is actively participating in cooperative programs under the sponsorship of the United Nations and other international organizations. Within the framework of the Committee on the Challenges of a Modern Society of the North Atlantic Treaty Organization, we are working together with other countries to develop and produce a new kind of automobile engine, which will be entirely clean. Earlier this year a very useful conference on this subject took place in Eindhoven, under the sponsorship of the Government of the Netherlands. We were keenly interested to learn of the progress made here in this field, with the development of a modern Stirling engine.

The United States Government also welcomes the opportunity to take part in more informal exchanges of view, such as this seminar. We are eager to learn from the experiences of other countries. We are also ready to contribute the results of our experiments, and our most advanced technology.

A seminar which will give specialists of this area of Europe and specialists from the United States the opportunity to compare problems, current projects existing technology and prospective technology is particularly appropriate at this time. It is timely because, important new laws have recently been passed and special new governmental organizations have recently been created. As a result it is possible for the first time to concentrate all national resources and all energies sharply on the battle against air and water pollution.

Our seminar is also very timely because, in this area of Europe and in the United States, closely related and promising research projects are now under way. New systems for measuring and controlling the various forms of polluting substances are under construction or in an advanced planning stage. In this connection I am following with particular interest the important projects now going forward rapidly here. One example is the new effort to purify at the source the water of the potato starch industry in northern Holland. Another is the automated network for identifying and measuring all forms of air pollution in the Netherlands, Belgium and Germany. The Rijnmond automated air pollution warning system is a Netherlands accomplishment which is very worthy of note.

Lastly, this is a good time for us to get together because a new mass industry has appeared on the international scene: the industry producing the technology and equipment necessary to give us clean water and clean air again. An industry producing anti-pollution devices has, of course, been in existence for a long time. Now, however, for the first time a mass market exists. As a result, new factories and laboratories are opening; others are undergoing sizeable expansion; and new patterns of trade and distribution are developing.

I hope that this seminar will provide possibilities for discussions--both formal and informal--of the economic and commercial opportunities which arise from the creation of this new industry.

I hope that representatives of European firms and organizations and their American counterparts will meet often to explore the possibilities for permanent relationships in the months and years to come. These relationships should include trade in the equipment which our plants produce, licensing of our technology, and other forms of industrial cooperation. In that way we can make sure that our joint technical accomplishments to date, and the technical breakthrough which we hopefully anticipate for the nearer future, will be of earliest and most direct benefit to the population of all countries.

The color green has been selected for the cover of the program for this seminar and its proceedings. It is the color of nature and of renewal. May the seminar help to take away the greys which are now disfiguring our surroundings, and restore the colors green and blue to their rightful place.

PERSPECTIVES ON ENVIRONMENTAL CONTROL POLICY

By Sidney R. Galler
Deputy Assistant Secretary for Environmental Affairs
U. S. Department of Commerce

The enactment of the National Environmental Policy Act of 1969 presented the people of the United States with the most comprehensive, enforceable Federal policy for the protection of the environment and the regulation of activities impinging on the environment in our Nation's history. What is not generally recognized is that the NEPA is more than a set of policies guiding the promulgation of standards and regulations for the protection of the physical environment. Actually, it represents a modern reaffirmation of a code of environmental ethics with which almost every sector of our national community will need to compare, evaluate, and, whenever necessary, reconcile its activities, business and industry not excepted. As in almost every instance of human endeavor, a legislated requirement to reconcile practices with ethical principles, no matter how wise and beneficial in the long term, often is accompanied by short-term social and economic readjustments, including severe social strains and economic hardships on some sectors of the community.

This is certainly true during the present transitional stage of development of measures for environmental enhancement. New and more stringent standards and regulations of environmental protection are producing a number of temporary socioeconomic strains during this period of readjustment. They range from relatively minor inconvenience to the individual householder to rather severe economic hardships on some industries.

However, our observations lead to the conclusion that the leaders of all sectors of the community in the United States recognize and accept our national environmental ethic. Certainly, the general public is irreversibly committed to receiving the benefits of environmental protection even though it does not yet possess a clear understanding of the costs involved. In the United States we are witnessing a dramatically increasing resolve and commitment on the part of business leaders, not only to comply with existing standards of environmental protection, but to take the initiative for the private sector in developing programs of environmental enhancement with socioeconomic benefits for the entire community.

At present, we are confronted with a number of problems that tend to inhibit the rapid development of effective programs of environmental protection. Some of these problems are readily susceptible to solutions. Others must await the acquisition of new knowledge and the development of improved and new technology. A few of the most note-worthy problems are cited:

1. The incompleteness of environmental data;

2. The inadequacy of ecological information required for the practical interpretation of environmental data;

3. Closely associated, the lack of reliable predictive ecological systems or models for estimating the kinds of probabilities of environmental impacts that could result from various kinds of proposed actions;

4. We need reliable technical-economic information planning systems for calculating the socioeconomic cost/benefits associated with options for complying with environmental standards.

In addition, there are a number of secondary, but no less important, environmental issues that will have to be resolved if we are to accelerate our programs of environmental protection.

1. A need to facilitate the transfer of knowledge gained from basic ecological research to engineering application. We must improve the "translation" of the language of the ecologist so that it can be more readily interpreted by the engineer and technologist.

2. We must improve both the reliability and accuracy of environmental monitoring instruments and techniques.

3. We must discover ways of accelerating the transfer of existing technology to environmental protection.

4. Closely related, we must find ways of encouraging technological innovation to improve our systems of environmental protection and enhancement.

5. We must develop mechanisms for predicting the "downstream" environmental constraints on developing technology as part of our technology assessment apparatus.

Although none of the aforementioned problems are insurmountable, their solutions will require a continuing substantial investment, both financial and scientific and technological. It is our hope that the exchanges of information and discussions associated with the environmental control seminars will be helpful in facilitating progress towards environmental protection with the greatest socioeconomic benefits for the entire community.

THE INTERNATIONAL COOPERATIVE EFFORT TO OVERCOME ENVIRONMENTAL PROBLEMS

By H. J. deKoster
State Secretary for Foreign Affairs the Netherlands

We all know that environmental pollution is a pressing problem, especially in the highly industrialized countries. In many cases it is only international cooperation that can offer the prospect of a final solution.

We are all becoming increasingly aware that our national environment is part of an ecological equilibrium, the disturbance of which cannot continue beyond certain limits. In the relationship of mankind to his environment, the latter imposes built-in restrictions on human activity. This is a challenge to the whole of mankind that can only be met in a spirit of constructive international collaboration.

It is difficult and in a way somewhat useless to draw a sharp distinction between environment issues of a purely national character and those of international concern. We know from experience that in the course of time, the international extent of the pollution problem has become greater and we expect that it will continue to grow in the future. Indeed, the international repercussions should be the concern of us all, whether they relate to transboundary pollution, or interregional problems of urban environment in border areas, or disruptions in the exchange of products and the free flow of resources. As in respect of many other urgent issues, we should develop an international consciousness also in environmental affairs.

It is generally appreciated that environmental issues, as they present themselves today, can broadly be ascribed to such factors as population growth, the advance of technology and expanding consumer requirements. At an earlier stage in our industrial development, we attach such great value to these factors, as being the chief guideposts of our economy, that we almost took our environment for granted. Our social ethics seemed to be that nature was subordinate to man. And economic theory had led us to believe that the resources of our environment were free of charge.

Only recently, here in Holland in the sixties, did people begin to recognize the importance of such "trivial" matters as clean air and clean water, and the need for more recreational facilities and better living conditions in general. Basic material needs were increasingly satisfied, and consumer preferences moved on to "higher" levels--in more than one sense Even more important, there has been an increasing awareness that ultimately our very survival is at stake. Our society awakened to the fact that our environmental assets were becoming scarce and were therefore becoming ever more valuable. Man became aware that he was not situated above or outside nature; he was part of it.

We are entering a new phase in which governments accept the consequences of an agonizing reappraisal of the value of environment to mankind. We are in the process of devising systems of legislation that will enable us to face up the challenge of environmental pollution. The new laws are no longer designed merely to prevent or remove the causes of sporadic pollution, as were the old regulations, but to ensure the purity and the health-giving properties of man's environment by deliberate and systematic action.

At the same time the nations are rapidly joining forces to meet the emergency and for various reasons:

1. In the highly industrialized countries the protection of the environment is becoming a matter of the greatest urgency and governments are spontaneously looking for international support for their national efforts. We have had recourse to international cooperation for many years in our attempts to solve many other problems--our security, the needs of developing countries, matters of trade policy and monetary difficulties. It seems to me quite obvious that we should now endeavor to cooperate internationally in matters of environmental control, if only to gain a better understanding of all the problems. By consulting each other, by exchanging information and by doing research work together we can find remedies for the ills that afflict our environment.

2. A second, more specific argument in favor of international consultation on the environment is that environmental pollution does not stop at national boundaries; indeed, a particularly frightening aspect of pollution is that it can affect the entire globe. Take the pollution of the oceans and the contamination of the troposphere and stratosphere by subsonic and supersonic aircraft.

   Regional trans-boundary pollution--affecting a few countries only--is also becoming an increasingly serious matter. Trans-boundary pollution problems call for effective forms of bilateral and multilateral cooperation with regard to such questions as water management, urbanization, industrialization and nature conservation, especially, though not only, in the frontier areas.

3. A third reason why environmental problems are being tackled internationally is that international trade may suffer as a result of pollution of the environment. It has been found that in some countries products may be required to satisfy such norms as would constitute additional non-tariff barriers to international trade. (Take for instance, the plans for legislation on pesticides drawn up in the United States Congress a short time ago, plans subsequently discussed during a conference of the Organization for Economic Cooperation and Development. I hope that the United States Government and Congress has heeded the critical views expressed by the experts attending that Conference). This poses the question as to the extent to which products standards (including design standards) should be harmonized internationally. Dr. Harold Passer, Assistant Secretary of Commerce for Economic Affairs, made some pertinent remarks in a speech on 26th April; he asked whether, within the United States, national or local (i.e. State) standards should be adopted:

"One of the basic issues still to be completely resolved is the question of uniform national pollution standards versus varying local or state standards... In many cases the overriding consideration dictating a need for uniform national standards is the effect that conflicting local standards would have on the nationwide market systems of many firms and industries. A producer of detergents could not make and market at reasonable cost a product that must satisfy hundreds of conflicting local standards. Likewise, automobile manufacturers could not design and produce, at reasonable cost, emission controls for cars that would satisfy conflicting State or local standards".

These arguments in favor of uniform standards within the United States are equally cogent in the international context. We shall have to make efforts internationally to harmonize our standards for products as much as we can, though some of our environmental problems may become so pressing that we shall not always be able to wait until international agreement has been arrived at before laying down national legislation.

4. Fourthly--there are other standards and norms besides those for products that should be set internationally. Consultations are in progress in such organizations as WHO and FAO on the harmonization of criteria, guides and standards in respect of the environmental factors themselves.

   Then there are the standards for the disposal of effluents as they enter the environment during the production process, i.e. regulations not directly related to the product proper, standards that trade and industry will have to satisfy--they should also be made the subject of international consultation. It should, in principle, be possible for emission standards in the various countries to differ. However, bilateral or multilateral regulations are a sine qua non where industries are located in frontier areas or contaminate international rivers or waters. In such contingencies efforts must be made to reach very specific agreement on the overall pollution that is nationally or regionally permissible. These matters are vital to the Netherlands, lying as it does in the delta of Western Europe: the equivalent of 250 kilograms of kitchen salt comes down the Rhine every second; intensive international discussions are taking place on the subject. All the same, there will have to be a certain amount of latitude for individual countries where such is possible without harming neighboring countries or upsetting the ecological equilibrium. Every nation will take its political decisions within those limits. Those decisions reflect the value a nation attaches to the quality of the environmental factors for its well-being. They determine the price the producer (and, of course, ultimately the consumer) must pay for the use of the environment.

5. Lastly, it is important to ensure that the views of governments are harmonized in respect of the allocation of the cost of envir-

onmental management within their national economies. Of course, this is also a matter that concerns enterprises that have to compete in international markets. The Netherlands believes that, in principle, the polluter should pay, that as a rule enterprises themselves should bear the cost of complying with any new regulations. If the enterprises in competing countries have to satisfy less stringent requirements, this may as a rule not prompt governments to give financial support or protection to industries which have to comply with more stringent requirements.

The advantage inherent in the principle that the cost of environmental management should wherever possible be made to appear on the industries' own cost-price accounts is that this ensures that resources are allocated with optimum effect. It also fosters the development of cheaper and cleaner methods of production.

The principle that as much as possible of the cost should be borne by the producer could be put into practice by introducing coercive regulations such as standards (i.e. preventive measures) or by imposing levies on enterprises. In the latter case the receipts would be used to rectify damage to the environment or to create alternative environmental facilities. A useful discussion on such issues has already begun in the Organization for Economic Cooperation and Development.

An important question is, of course, what economic impact all these measures would have. This would depend essentially on how technology meets the new environmental challenge. It would be a great advantage if new industrial technologies, including the recycling of waste, could in the long run compensate for the short-term effects of cost increases. At all events, a new orientation of our economic structure, both by sector and region, should certainly be expected as a result of our environmental activities.

The work of international organizations: the European governments are cooperating in a number of international organizations in matters of environmental management. A few of them will be mentioned. One is the Council of Europe, which plays a vital part in nature conservation and which can also do much in the sphere of legislation. Trans-boundary pollution problems affecting both East and West are discussed in the ECE; for example, the symposium held in Prague in May, 1971. There will have to be far-reaching "environmental integration" within the expanded European Community. We are also cooperating in matters of environmental management in the narrower context of Benelux.

In other organizations we have the privilege of working together with the United States. It appears that in the United States environmental problems are being tackled most energetically and with great perspicacity. We should be able to benefit by the experience gained by our American friends as we cooperate with them in various international organizations, such as the Organization for Economic Cooperation and Development, in which among other subjects the economic and trade policy aspects of environmental pollution are discussed. This cooperation between countries that have much in common, as regards both their economic systems and, alas, their potentialities as pollutors, will hopefully prove successful. Then again, we are cooperating in the United Nations family. WHO, FAO and other organizations are doing most important expert work. In June 1972 there will be a noteworthy event--the United Nations Conference in Stockholm. At this Conference problems of environmental control are to be dealt with in close cooperation with developing countries. However, we should not lose sight of the fact that many of these countries look upon the problems with mixed feelings. They do not know whether or not the combatting of pollution in developed countries will be to their disadvantage since it is bound to make industrial products more expensive. They do not know whether or not environmental rules may hamper their basic economic development. Yet the interests of developing countries are also at stake. I believe a recent report on pollution in metropolitan areas contended that the most polluted cities in the world are Seoul, Taipei, Ankara, Mexico City and Buenos Aires, in that order.

Last but not least, there is NATO, within which a number of pilot projects have been launched, the initiative having been taken by the United States. A conference on "clean" internal combustion engines was held recently at Eindhoven under the auspices of NATO. The rapid expansion of international cooperation in recent times also unfortunately has disadvantages, not only for travel-weary officials. Experts are few and far between; they have to divide their attention, because they have to attend too many meetings. If only for this reason, we should constantly endeavor to achieve optimum efficiency in the division of labor over the various international organizations. The environment is such a vital matter, however, that we shall have to be patient as we pass through the initial stages and give the organizations a chance gradually to achieve an efficient division of labor.

Finally both science and industry have a vital part to play in the solution of our environmental problems. It is their task to make it technically possible to combat environmental pollution and to do so at reasonable cost. It is to science and industry that the authorities look, as also to the citizens and the consumer, for support in the implementation of their policies.

May the seminar be a great success; may constructive discussions serve to clear the air, both figuratively and literally, and give us clean water to drink and a clean world to live in.

OBJECTIVES OF ENVIRONMENTAL MANAGEMENT POLICY IN THE NETHERLANDS

By R. J. H. Kruisinga
State Secretary for Social Affairs and Public Health

The exposure of man to an increasing number of complex environmental factors, many of which are hazardous, requires the re-examination of environmental control programs and policies. Man's health is main concern of nations in their endeavour to restore the quality of man's environment.

Changing Emphasis

Basic sanitary programs for the prevention of communicable diseases were given highest priority during the early decades of environmental health activities. This approval is still valid today, anywhere and at any time, and continues to be the safeguard against the spread of epidemics.

The application of modern technology and the subsequent economic growth have given rise to new environmental pollutants discharged with wastes from industrial processes, pesticides, chemicals added to food during production and processing and chemicals in households.

The pollution of air, water, soil and food is aggravated by our ways of life in large metropolitan agglomerations and associated stress, such as crowding, noise, radiation, transport and accidents, and occupational risks. A new ecological view of human health is emerging, which emphasizes the inter-dependence of health and environmental conditions and their control.

We are in a stage of technological development where the need to give "due consideration to the effect of water, soil and food and air pollution, noise and other environmental factors harmful to human health should be stressed, and where the need for the establishment of environmental health criteria and guidelines for preventive measures, and methods of determining priorities and allocating resources based on health needs is urgent."

Scope of Environmental Health Programs

A program in environmental health should reflect both the continuing need for the essential sanitary measures and for response to new and adverse environmental factors and conditions. Specifically:

1. Basic sanitary measures in urban and rural areas--The objective of this part of a program is the provision of essential environmental sanitation in rural and urban situations, to prevent and control communicable diseases and promote mental and social well-being.

   This is accomplished by the provision of water supplies, sanitary disposal of excreta and sewage, provision of housing satisfying basic conditions of hygiene, community sanitation including food sanitation and vector control, and other means essential for the general physical and social conditions of life which are also a pre-requisite of improved health.

2. Control of environmental pollution and other hazards--This part of a program should aim at the reduction of air, water, land and food pollution and of physical hazards such as noise and radiation to levels which permit optimal economic development without creating hazards to health or significant disturbances in the ecosystems.

   This has to be accomplished by establishing national and international environmental monitoring systems, adopting environmental quality criteria and standards, applying appropriate technological, legal, administrative and other control measures, introducing changes in industrial, agricultural and transport technology, and initiating research programs into the effects of pollutants, their behavior in the environment and into the methods of reduction and treatment of waste products of man's activities.

3. Urban-industrial environmental health--This should aim at optimal environmental conditions in urban-industrial areas and prevent or control of the harmful effects of urbanization and industrialization.

   It should ensure maximum benefits for the health of the people. This will include an appraisal of the hygienic conditions of housing, of the health implications of urban, metropolitan and regional development, health implications of land use, health implications of transport systems and of work conditions. It should include the establishment of quality criteria for the urban-industrial environment including transport systems. It should include incorporation of health considerations into the processes for urban-industrial and neighborhood development and the initiation of research on health risks associated with life in urban areas.

4. Planning, infrastructure and institutions for environmental health programs--This should create an infrastructure and institutions capable of conducting effective planning and management of environmental health programs and of integrating these into national or regional health and general development programs and policies.

   This has to include the assessment of the environmental health situation, the application of planning models to environmental health, including consideration of economic implications. It must consider the training, mobilization and effective utilization of human resources to meet the local and national needs. And it should pay due attention to appropriate legislation both national and international. The establishment of applied research institutions in the field of environmental health should thereby be considered.

   Nowhere in the world is it possible today to limit environmental health programs respectively to the provision of basic sanitary measures or the prevention of environmental pollution only. Most countries are faced with several or all of the environmental problems. An appraisal of each situation will disclose which problems are particularly critical to a given country at a given time.

Need for Greater Efforts in the Above-Mentioned Areas

Work in environmental health will need to extend into all four areas referred to above, and produce four distinctly different outputs for each of them. Specifically:

1. Information--This will include the generation and verification of reliable technical information inputs on the levels of adverse or beneficial environmental conditions and factors, and environmental needs and programs and effects of environmental conditions. This should be done together with the development of methods and instrumentation for the generation of valid information as well as the institutional arrangements required. It means the development and testing of indicators and parameters suitable for evaluation, control and epidemiological research relative to environmental factors and conditions. This has to be a co-operative effort of the different countries based on Collaborating Institutions in environmental health.

2. Environmental health criteria--They include quality criteria for air, water, food, land and soil. They include acceptable levels of environmental radiation and noise and other physical factors. They include also criteria for environmental exposure; minimal requirements for the quality of housing and neighborhood, including recreational facilities.

   The bases for the establishment of environmental health criteria should be (1) direct effects on health, where known, (2) the desire to keep adverse exposure at minimal levels where effects cannot yet be demonstrated, (3) the public demand for the maintenance of a high quality environment taking into account environmental changes and effects which may indirectly affect man's health.

   The setting up of environmental health criteria will involve the examination and evaluation of national criteria standards for environmental health. It will also involve the critical appraisal of the evidence of the effects on health and the environment.

3. Guidelines for environmental improvement and control--This output should provide practical guidelines and codes of good practice for planning of environmental health programs and their implementation including technology. It should provide legislation, administrative and intitutional requirements, and the training of manpower, both for basic sanitary measures and environmental quality management.

   They should be based on an appraisal and evaluation of information and technology existing in some parts of the world, and of the needs existing in others. Field and pilot studies and supplementary research should be initiated in this respect.

Priorities in the Environmental Health Program

As noted earlier, in the past the work in environmental health has focused on the introduction of basic sanitary measures in urban and rural areas as a means of controlling communicable diseases, and has been focused on creating institutional agencies for environmental health, with nuclei of human resources. A shift of emphasis, outlined above, should now take place, with re-orientation of programs and re-establishment of priorities.

Information, environmental health criteria and guidelines, together with methodology for environmental health planning and allocating resources based on health needs are instruments for priority decisions and should be developed.

Parallel to this, environmental pollution and other environmental factors harmful to human health should be part of a program, complementary to the provision of the basic sanitary services. This re-definition of programs and outputs fully reflects existing conditions in the human environment. It will be necessary to revise the priority objectives and to include such additional priority items that are needed in view of the changing conditions of the human environment.

These may include: (1) an increased emphasis on the provision of facilities for the sanitary disposal of wastes; (2) steps towards establishment and operation of a specified number of stations for the monitoring of adverse environmental parameters together with the necessary institutional arrangements; (3) preparatory steps, especially legislative and institutional, for the prevention of environmental pollution and other hazards at the local, regional, national and international level, as applicable; (4) creation of an environmental health infrastructure and institutions capable of planning and conducting environmental health programs by the end of the decade; (5) creation, or strengthening, of a specified number of training institutions for specfied human resources for environmental health.

A Code of Environmental Health has to be established. One of the purposes of a code of environmental health should be to indicate the sequence of stages through which environmental health programs may evolve, such as the control of communicable diseases, the provision of adequate water, the sanitary disposal of waste, the sanitary handling and storage of food, occupational health, housing and other problems of urbanization, the prevention of air, water and soil pollution, noise control and others.

One of the purposes of this code also should be the development of guidelines standards and criteria for those many new environmental factors that have an adverse side-effect on the health of mankind and the health of the environment.

An Historical Perspective of the Human Environment

If we look back at the last century and gaze forward towards the approaching decades that already mean the end of a following century, and while so doing try to consider the interaction of social development and the development of health, we come up against a remarkable and disturbing paradox.

It is striking how, in the second half of the last century, health control measures, with a particularly limited knowledge of causal mechanisms and a minimal understanding of human physiology, nevertheless managed to achieve great successes in the control of the then prevailing endemic diseases and plagues threatening health. We need think only of smallpox, of cholera and typhoid, and of rickets and endemic malaria--which was so greatly feared that the reclamation of one of the Dutch lakes the Haarlemmermeer was nearly abandoned because of it.

While medicine today has a detailed and often thorough knowledge of the causes of the endemic diseases of the present time--cardiac and vascular diseases, cancer and also neurosis--and though we moreover have at our disposal a technical and therapeutic arsenal such as never before, we still have not so far proved capable of halting the growing depradations of these diseases in society.

Of course we are aware of the great importance of modern therapeutic possibilities for the treatment of the individual patient, of which we certainly may be proud. It is however a chilling paradox that a century ago, with such little knowledge, so much could be done about the endemic diseases then threatening society whereas now, with our much more thorough knowledge and better equipped science, the health problems threatening the community are growing to a serious degree.

The technical development of health care and medical science makes large investments necessary, also so as to be able to apply the many new and important discoveries in health care. The total level of investments in health care has greatly risen in recent years. There is an unprecedentedly high level of material investments in health care. Yet, for all that a number of health indicators are tending towards worse figures than in the Fifties, a tendency which is general especially in countries with a high and still rising national income.

It seems a paradox. Is it? There is another apparent paradox.

Man's health in the second half of the 20th century is threatened in the first place by increasing prosperity, or rather by an increase of the level by which the prosperity of a nation is still measured today; national income, national product and other economic indicators still in use.

The further life expectancy of males, which with other health indicators had regularly risen until the year 1950 under the influence of better medical care and better hygienic conditions, now displays a clearly declining trend notably for males aged 30 and males aged 45.

It has to be admitted that, despite the enormous increase in medical possibilities, it has not proved possible to call a halt to this phenomenon. Until recently it was still true to say that the harmful secondary effects of the so-called growing economic prosperity had not come to light. New possibilities created by the technological medical revolution outweighed these negative effects. This phase is now past.

Drawbacks to the Growth of Prosperity

The positive technological development of health care is unable any longer to make so large a contribution to the improvement of the Dutch people's state of health as to outweigh the harmful secondary effects of economic growth on that state of health. These harmful effects cover a wide field:

Every year we number in thousands the victims of road accidents.

Every year in Europe there are now more than 150 thousand deaths--not only from lung cancer but also from heart disease--caused by the increase in cigarette-smoking.

A growth in venereal disease, both syphilis and gonorrhoea, may be noted throughout practically the whole of Europe.

Every year drugs in all their various forms are claiming more victims, especially young people. In most European countries the number of young people who have to be admitted to psychiatric hospitals is on the increase. For the age group of 20 to 24 years hospitalization on account of alchololism and drugs is particularly disturbing in European countries. In a few countries about 25% of the admissions to psychiatric hospitals in this age group were caused by abuse of drugs and alcohol.

The effects on our physical health of numerous physiologically active substances present in the environment deserve our full attention in the next decade.

These substances doubtless have their influence on the biochemical processes going on in the human body. On the one hand we know of many substances which, used as medicine, foster health. On the other hand we are threatened by substances unintentionally present in the environment that we must characterize as pollution. Three examples from among many:

1. The concentrations of chlorinated hydrocarbons found in mother's milk for babies, persistent pesticides administered about the acceptable dose.

2. The direct introduction into the external environment of mercury compounds via use. In this country between 3,000 and 4,500 grams per square kilometer of pesticides containing mercury are used every year. The average annual influx of mercury into The Netherlands via the water of the Rhine is about 100 tons, or an average of some 274 kilograms per day. The investigations into the effect of mercury on human health in Japan are in no way reassuring.

3. Chemical mutagens in the human environment to which an increasingly important role must be assigned. Hereditary defects are coming increasingly to the fore, comparatively speaking. In fact this means a relative increase in the number of cases of illness and mortality that may be attributed to mutations. For instance, at least 2 to 4% of live-born children are characterized by a hereditary disease or defect. Mutations have been a natural occurrence since life first appeared on earth. Only during the last forty years has it become known that mutations can also be caused artificially.
   This was first discovered for X-radiation and other radiations released in radioactivity. Not until after the Second World War did it come to light that chemical substances too can cause such far-reaching transmissible effects in genetic material.
   These changes in hereditary material are of a dual nature--mutations, that is to say changes in the individual genes that are not microscopically visible, and breaks in the chromosomes that may give rise to chromosomal defects.
   Common to both is that they have mainly adverse effects of future generations inheriting them. For this reason an increase in the number of mutations and chromosomal defects as a result of these substances has serious consequences for the physical and mental well-being of these generations living after us.

Nor have been mentioned the still inadequately investigated consequences of numerous measures affecting the mental and physical health of people, such as housing, for example.

Recently attention was drawn--rightly so--to high-rise blocks of flats as a source of mental traumas on account of the lack of freedom, the nuisance from noise and the loneliness.

Those are a number of aspects of the other side--the health side-- of the coin called prosperity. This does not represent a cheerful picture of health for the future!

A comparison with the 19th century, with the start of the Industrial Revolution, now imposes itself on us. A look back teaches us that the factors that were inherent in the new conditions of life, such as developed as a result of that Industrial Revolution, led to a marked decline in the state of health during the 19th century (malnutrition, alcoholism, contagious diseases, tuberculosis). The same countries only gradually managed to overcome the consequences of economic development in the sense that they proceeded to create for man the hygienic conditions required in order to make a real adjustment to the changed conditions of life.

But, at the very moment when the solution seemed within reach, other problems loomed up, problems that are now the consequence of another set of new and changed economic conditions, entailing environmental pollution, poisonous industrial waste, exhaust gases of motor vehicles and "unhealthy" ways of life. And so we are once again confronted with major problems of health, as for instance those in the field of cardiac and vascular disease, cancer, mental and nervous diseases, which are bound up with the ability of the population to adjust to new changes in conditions of life.

Huizinga, a great Dutch cultural philosopher, clearly saw the coming sufferings of the present time in his "Shadows of Tomorrow" and analyzed essential elements leading to these phenomena of crisis.

In what he calls "a diagnosis of the spiritual suffering of our day" he states the following: "If we consider the economic and the political processes of disturbance together, then, looking at their gradual progress, it would seem to amount to the fact that for more than a century now the control of means has achieved a degree of perfection at which the social forces, not regulated and combined by a principle transcending the aims of each of these forces in itself, all operate for themselves with an excess of individual purposiveness that is injurious to the harmony of the organism in its totality."

Huizinga is referring here to the means of mechanical production and technology in general, of working, of publicity, of mobilization of the masses by political or other organizations. If the development of each of these means or forces is considered in itself, the concept progress may be applied to each individual aspect. All have grown tremendously in power.

Only nineteenth-century optimism could attach to the geometric concept progress the simple meaning "the bigger the better." However, starting from our present knowledge questions like the following arise:

What will be the motives that will guide society in its future actions?

What will be the incentives determining the steps taken by society?

On what spiritual foundation, which will be needed more than ever before, will that society be based?

From what source will society derive its inspiration, and what will be the touchstone for its actions?

What is the point of departure of those actions?

What are the points of departure that will form the criteria for statutory regulations in that society?

If we now conclude that the results of scientific and technological development, for whatsoever reason, have still found insufficient application in the field of health, we have to admit that we have not yet been able to apply scientific and technological development in a balanced fashion to further man's well-being and the well-being of his environment.

An exact inventory will have to be made of the factors that are important to the level of health of man and of his environment. The significance of those factors for physical and mental health will have to be established. In this field there is still a great deficiency of knowledge of the relevant facts and relations. Great activity to find those facts and relations is absolutely necessary. In particular the influences that can make themselves felt over longer periods will call for attention. It will also mean paying greater heed to the development of the epidemiology of non-contagious diseases and symptons of social well-being and social illnesses.

In addition, integrated planning is necessary. After all, for the future planning of health of the environment and of the human being is of the greatest importance.

In any case, in this context we whall have to admit that planning in the field of environmental hygiene has not yet been adequately integrated in the planning of economic development as a whole. For a basic national policy this will in the future be an essential condition. That at this moment we see nowhere this integration of the health and social planning with the economic planning is to a considerable extent the result of the too isolated approach of those concerned with economic planning.

Many are still too much under the influence of old theoretical ideas and trends and of partly outmoded economic approaches. In itself, this situation is not surprising. Economic analysis, which still forms the basis for what is called welfare policy, is still mainly based on the study of phenomena with regard to prices and market situation.

The value of services to the health of the population and the maintenance of the environment in which we live is still often regarded simply as a negative element in the acquisition of prosperity. In joint responsibility we are faced now with the important and stimulating task of developing the chapter of economics and politics in the service of man's health and of a healthy environment. If we are not to lose our gains in the field of the health of the people and its environment, further-reaching and also new measures will have to be taken to maintain an acceptable situation.

Regulating mechanisms required to counter environmental pollution. All resources will have to be applied in the most efficient and effective way possible in the service of man and the environment in which he lives. This means that control mechanisms have to be incorporated in what is going on in society to further the improvement of the environment in which we live. Investigations should further be made to establish which mechanisms tend to ruin that environment. That means the introduction of more and of new instruments to further prosperity by controlling pollution, also in a psychohygienic respect. It will be our joint responsibility to ensure that during a specified period the means and objectives of our society are combined into a rational pattern.

The economic aspects of health care and environmental hygiene--to a certain extent they supplement one another--are difficult to establish, as long as we confine ourselves to the traditional categories of consumption, saving and investment. In other words as long as we adhere to a distinction between what is said to be consumed and what is not. Social development is partly--indeed very largely--assured by the maintenance and improvement of the population's level of health, and not only by the consumption of more goods.

Too little attention has been paid up to now to Alfred Marshall's view that among other things food is both an intermediate product and a consumer good. In the same way we can also place expenditure for the maintenance of a healthy environment and of healthy people in the category of productive consumption. And that is done, consciously, or unconsciously, but rightly, in a number of recent publications by authors who assume that expenditure in the field of health care and environmental hygiene relates to what may be called "human capital." Within this framework expenditures on health care and environmental hygiene may be regarded as an investment.

It is appropriate to go somewhat further into the approach of the present method of quantifying national income in relation to what I have called the bill for the damage done by production activities in our society. Quite wrongly, the bill that has to be footed by health care and environmental hygiene has so far been entirely ignored when considering this problem.

If establishing a major industrial concern somewhere renders investments necessary in, for instance, the water treatment sector, then ultimately those activities are even included in the total contribution of that establishment to national income. In the final account they are jointly presented to us as contributions towards economic growth, quantified as a rise in national income. The increase in national income calculated in this way is misleading and incorrect as an index, an indicator for the growth in prosperity.

To derive an undistorted picture of the consequences which establishing that form has for prosperity, the investments for water treatment ought after all to be deducted from the contribution that this establishment makes to economic growth. And that is quite apart from other question marks that may be placed behind the unnuanced use of national income as an index to prosperity. For that reason future social and technological development will make it necessary to apply a more gradated economic planning than that to which we have been accustomed to in the past.

For otherwise in the future a steadily growing tension will come into being between what is regarded as economically desirable and what is necessary from the point of view of health care and environmental hygiene. From the angle of our joint responsibility it may be asked whether it is not becoming high time at least to complement thinking in terms of purely economic growth by thinking that is explicitly directed towards the achievement of a healthy people and a healthy environment. In that view, for instance in a decision about investment, not only the effects of this on the firm in question ought to play a part, but also the hygienic and social implications. The studying and solution of those problems will be of great influence on our future welfare policy.

Industrialization provides greater production, but from this we have to subtract the damaging side-effects, the negative side-effects from the industrial productivity as such.

And we have also to pay for these effects. This will have to influence our price mechanism.

The price mechanism now does not function in a proper way. As long as we do not charge pollution products their full price in as far as they do damage to environments, we are subsidizing those products. We are then promoting production of these products and discouraging production of non-polluting products. With this price mechanism we have an inbuilt katalyzer for polluting the environment.

The solution of the two point just mentioned:

(1) correction of our national production figure with the costs of economic growth and

(2) correction of our price mechanism in order that the real full price is paid for polluting products and polluting processes

is absolutely essential for solving our environmental pollution problems.

Conclusion

We live in strange times. Our prosperity is regularly incresing from year to year.

That seems a paradox. But is it?

What do we really mean by prosperity when we note the annual increase in prosperity? It may be asked whether a standard of living expressed in terms of money may be the goal and the universal criterion of human well-being.

In the last hundred years the consumption of industrial products has increased hundredfold.

What more do we want?

Yes what more do we want?

May prosperity, may well-being not be more than economism? Is prosperity, is well-being not more than stepping up the total figure of productivity?

That is certainly the case; of course it is so; practically non-one will deny that.

And yet it is the material quantitative approach that I have outlined which for decades now has dominated the view of society throughout the world and still dominates it today, in the west and the east, the north and the south.

It is only very recently that authoritative figures have dared to raise their voices against this: Kenneth Galbraith in his Liberal Hour, Rachel Carson in her Silent Spring, Ernest Zahn in his Leven met de Welvaart, Gunther Schwab in his Tanz mit dem Teufel and Mishan in his Costs of Economic Growth.

It is only a very short time ago that Galbraith ventured to point to what he called our short-sighted preoccupation with production and material investments that distracts our attention from the much more urgent question of how we use our resources and above all direct them to the greater need for and possibilities of investment in man.

It was not until 1963 that Rachel Carson wrote her Silent Spring, in which she asked what we are doing with "our" earth. She pointed out, for the first time in world history, that everyone is exposed to unknown chemical substances, synthetic substances so thoroughly distributed over the animate and inanimate world that they occur practically everywhere, in subterranean streams that flow unseen beneath the earth and in the fat of penguins at the South Pole.

It was even more recently, in 1967, that Mishan published his book entitled "The Costs of Economic Growth," in which he discusses the no-choice myth with regard to the balance of payments and in which he asks the rhetorical question whether it is not becoming time for us to start thinking about directing our one-sided, quantitatively oriented policy of economic growth towards a more selective policy aimed at furthering human prosperity and human well-being.

One does not have to be a prophet to predict that these are voices which will multiply in the future and sound ever louder.

These are also voices that regard healthy people in a healthy environment as one of the main aims and not as one of the secondary objectives of a financial, economic, tax, welfare or well-being policy.

Certainly for small, densely populated and highly industrialized countries like The Netherlands, international cooperation in this very field is vital.

In The Netherlands at the delta of the large European rivers, with the largest harbors in the world, the largest refinery concentration, the most densely populated area, there the problems of this type will let themselves be felt earliest in their most vigorous form.

There is no hope of sloving these problems without close international cooperation.

ROTTERDAM, ENVIRONMENT AND COMMERCE

By W. H. Fockema Andreae
President of the Rotterdam Chamber of Commerce and Industry

Just like any industrial country in The Netherlands, environmental problems have become a subject of public concern. In this country, and even more in Rotterdam, we have been studying and discussing environmental problems intensively during the last years.

Environmental problems are not unknown to the Rotterdam area. Long before the rapid industrial development of Botlek and Europoort started after the second world war, our people had been confronted with pollution from other sectors of the economy in our own area or from sources outside our area. The Rotterdam drinking-water, coming from the river Rhine that passes the biggest industrial agglomerations of the European continent before it reaches Rotterdam, has always had a special flavor. Some very conservative inhabitants of our city complain about the amelioration of the quality during the last years--just like some more or less professional jokers who are losing a source of inspiration.

Environmental control has become one of the most important issues of the industrial society of the 1970's. Especially last year the United States, Japan and Western Europe were confronted with a strong and often emotional reaction from the public against different types of pollution. Therefore government and business life have to realize that the man in the street is worried about his environment. We shall have to realize that with an increase in welfare, demand will increase not only for the products of modern industry, but also for the free goods like fresh air, fresh water, nature and silence, that become scarcer.

I think we cannot do away with these emotional reactions by saying that it is not possible to have a rational discussion with those, especially of the younger generation, who protest against the menacing deterioration of our environment.

First of all we shall have to explain to them, that environmental problems are by-products of the welfare we enjoy nowadays in the industrial world.

Without industry and the products of industry, pollution might be smaller, but welfare also would be smaller. On the other side we should consider the possibilities continuation of economic growth offers us for developing techniques and systems to reduce environmental problems as much as possible.

Secondly, we should explain that in our complex world it is not only industry or business life in general that is causing pollution, but that the consumer has his free choice in buying goods and services that cause pollution of different types. Pollution caused for instance by exhaust-fumes of cars is the consequence of the wishes of all of us as consumers. If we as consumers are prepared to pay a little more for privision in our cars and our gas to purify the exhaust-fumes, industry will certainly be able and willing to supply the technical devices.

We shall have to explain also, that the fight against environmental problems is not only a matter of technical innovation and government legislation, but that it will lead also to an increase in the costs of production--and sometimes even distribution. This will result in higher prices for products with a high "pollution content" but we should not forget that in our growing economy we will be able to pay for this, and that we can reach a higher level of welfare and well-being.

Finally, we shall have to explain not only to the public, but also to governments and business-life, that environmental problems should be dealt with in our "worldwide village" as international problems.

Air and water pollution do not stop at the frontiers and not even for the oceans, so here the need for international cooperation is evident. But international cooperation is also necessary to prevent distortion of competition. If one country takes those problems seriously and another country does not take effective steps to fight pollution, firms investing in the first country will be at a disadvantage, and the same thing applies for export-products from that country. As it was rightly emphasized during the Congress of the International Chamber of Commerce in Vienna last month, organized business life and governments will have to work for an international coordination in the fight against pollution.

ENVIRONMENTAL MANAGEMENT IN POLAND

By W. Janiszewski
Vice-President, Central Water Resources Board (CUGW)
Warsaw, Poland

The problems connected with the human environment have been noticed and undertaken in Poland relatively early. The State Council for the Preservation of Nature, as an advisory body to the Government has been acting since 1919, and the League for the Preservation of Nature, a social organization, popularizing the ideas of the nature preservation has been acting since 1928.

Several elements of the human environment as geosphere, hydrosphere and atmosphere are in Poland under legal protection on the basis of issued resolutions and decrees. Taking into consideration the extremely wide and comprehensive aspect of the problems of environmental protection and rapid economic development, one of the most important questions is to ensure full cooperation and coordination of all involved institutions and organizations. As a consequence, the interdepartmental coordinating body, the Polish Committee on Human Environment Protection, was called into being in 1970 by the Order of the Prime Minister.

The Deputy Prime Minister is the Chairman of the Committee, the vice-chairmen are as follows: President of the Central Water Resources Administration; President of the Polish Academy of Sciences; Vice-Minister of Foreign Affairs; Vice-President of the Planning Commission by the Council of Ministers; and the Vice-President of the Committee of Science and Technology.

The representatives of several interested Ministries, Committees and social organizations are members of the Committee.

The main tasks of the Committee, which is the governmental advisory and coordinating body are initiation, appraisal and coordination of activity of the Ministries and institutions involved in environmental protection and also determination of the trends and scope of cooperation in this field with international organizations.

The tasks of the Committee are as follows:

Consideration and evaluation of the relationship of environmental problems with long and short term planning of economic and social development.

Suggestions for governmental long-term policy in the field of human environment protection.

Consideration and giving opinions on long-term plans of governmental departments and institutions in the sphere of human environmental protection.

Review and initiation of the legal acts and decrees relating to the rational management and control of environment.

Review of actions and international programs in the field of environmental protection and also initiation of cooperation with international organizations.

Initiation and evaluation of comprehensive studies in Poland as well as the control of the scientific and technological progress in this field.

The atmosphere and water resources have the most important meaning among the components of the natural environment. The Central Water Resources Administration has been charged with the management of these problems through planning, coordination, determination of the principles and methods, initiation of the legal acts, control and supervision.

The problem of air pollution is continuously increasing and its social and economic aspects are becoming international ones. Air pollutants are transferred very often to places beyond the boundaries of one country so the struggle against their effects on the natural environment and human life requires comprehensive preventive means, not possible to be undertaken by an individual country. So, it is necessary to underline that only the common and coordinated effort undertaken by many countries can restrain the increasing pollution and devastation of the natural environment and also the negative changes of living conditions in industrial regions.

The present emission of air pollutants in Poland is estimated to be about 4 million tons of dust and about 3 million tons of sulphur oxides annually. The problem of air pollution is most acute in the Silesia-Cracow Industrial Region, which apart from the Ruhr Coal Mining Region in German Federal Republic, is the area of the highest concentration of heavy industry in Europe. The greatest devastation of nature and especially of the conifers is observed in this region. The reconstruction of forests has been commenced in these areas. The resolution on atmospheric pollution adopted by the Polish People's Republic Seym in 1966 and the executive acts issued during the period 1966-1967 created the legal basis for air protection in Poland and enabled the activity leading to the limitation of the harmful influence of industry on environment.

The efforts already undertaken so as to improve the situation in the field of air protection have been directed mainly to:

Recognition of the present status in the field of pollutants emission in the industrial regions of the country as the principal condition for the elaboration of programs of activity.

Counteraction against further increases of air pollution and its harmful effects on the natural environment by using the adequate technical means.

Activity in the field of air protection has already given measurable effects in the struggle against dustiness caused mainly by electric power plants and cement factories and has enabled the utilization of the volatile dusts in the building industry. A further decrease of dust emission by about 17 per cent is foreseen by 1975.

The technology of the dedusting process has been recognized in Poland and it is being continuously improved. Now we have plants manufacturing dust-collecting facilities which are of high effectiveness, especially electrofilters. Further efforts in this field are being aimed at the development of a production basis by the organization of new design offices.

The main trend in the air pollution control in the future will concentrate on the limitations of emissions by technological changes in production processes, proper exploitation and maintenance of the facilities for treatment of gases emitted to the atmosphere, heating network construction, etc. Central heating and gasification in cities and electrification of railways are being utilized more widely than ever before.

Many cities in Poland have very considerable heating networks both for heating and technological purposes. It has enabled the considerable improvement of situation in Lodz, for example, the biggest textile industry center in Poland. Similarly, Warsaw, 50 per cent of which is heated by two big electric power plants is, in spite of the industry located there, one of the cleanest cities in Europe.

Further development of air protection depends, first of all, on the results of scientific and research works and proper recognition of air pollution status. At present in Poland about 40 scientific and research institutions have included in their plans of research works the problems of air protection. However, extremely wide problems of the scientific and research works are beyond the possibilities of even highly developed countries of the world. These problems can be solved, first of all, by international cooperation. At present Poland takes part in efforts on these problems as a member of the Council for Mutual Economic Assistance and the Economic Commission for Europe as well as in organizing the international conferences and seminars.

The problem of water protection against pollution is also of great importance in Poland. The continuous increase of the quanity of wastes resulting from the economic development of the country and the increasing population creates the necessity of the struggle against river pollution and connected with this the difficulties in supply with water for the population and national economy.

To illustrate the problem the following figures may be quoted--the quantity of wastes in 1960 amounted to about 4.8 billion cubic meters and in 1970 it reached about 8.0 billion cubic meters. Thirty-five per cent of river courses in Poland are polluted to a degree exceeding the admissible standards.

In order to improve the situation and first of all to prevent further harmful effects, the elaboration of a long-term program of activity based on proper legal, technical and economic bases has been necessary.

The legal basis for activity in the field of water protection against pollution is the "Water Law," the resolution issued in 1962 along with the executive acts. It adjusted the previous legal acts in this field to the contemporary social and economic conditions in the country.

The above-mentioned acts determine the obligations of industrial plants and people discharging their effluents into waterways and conditions for issuing permits for wastes discharging and requirements for water quality in accordance with their utilization.

The activity in the field of water protection against pollution is conducted by the State Inspection for Water Protection acting in the framework of the Central Water Resources Administration. Also this activity is conducted by 20 voivodship divisions of water and air protection through about 100 local units. The divisions have laboratories for water and wastes studies which deal with the laboratory control of pollutants in effluents discharged by industrial, municipal and other plants, as well as with the measurements of surface-water quality. Work in the field of water pollution control concentrates on three main directions:

Design, construction and operation of treatment facilities.
Control of the execution of the regulations on water protection.
Scientific works.

In the field of the design we possess the resources enabling us to work out the required documentation for the construction of treatment plants despite the increasing number of tasks in this field.

The special office to ensure the optimal organization of the design effort has been called into being within the framework of the Ministry of Building and Building Materials Industry. This office coordinates the works of 80 design offices dealing with the treatment plant designs.

The intensive investment activity in the field of treatment plant construction is being conducted so as to prevent the harmful effects of wastewaters.

While determining the priorities for investment in treatment plants plans the principle is to concentrate the expenditures first of all on highly economically developed basins of the Upper Vistula and Upper Odra Rivers, the two biggest rivers in Poland, where the difficulties with water supply of adequate quality are especially observed.

A considerable part of the expenditures is destined for regions especially to be protected because of water intakes, tourism, recreation, etc.

The activity mentioned above has limited the increase of river pollution despite economic development of the country. However, a general improvement of water quality has not yet been achieved.

The scientific works in the field of water protection against pollution in Poland are being carried out by about 60 institutions and scientific institutes employing about 600 highly qualified specialists of various scientific disciplines. The considerable part of these works executed by the different bodies and dealing with the technology of effluent treatment is coordinated by the Central Water Resources Administration.

Among the above-mentioned scientific and research institutes dealing with water and wastewater the following should be mentioned: the Water Economy Research Institute, the Research Institute for Municipal Economy, the State Hygiene Institute, the Main Institute for Mining, the Research Institute for Ferrous Metallurgy, and the institutes of the Polish Academy of Sciences.

The main directions of the investigations involve the following problems:

Improvement of treatment technology and construction of facilities in specific industries.

Reuse of wastes in production processes in closed cycle systems.

Water self-purification processes and determination of the admissible pollution standards.

Recovery of raw materials contained in wastes.

Management of waste sludge and solid wastes.

Methods for the counteraction against causes and results of water eutrophication and pollution caused by fertilizers in agriculture.

Certain achievements in several fields can be mentioned:

Improvement of the methods and facilities for phenols recovery from ammonia water in coke by-product plants.

Elaboration of the biological method for treatment of phenol wastes by the activated sludge process.

Elaboration of the biological method for treatment of phenol wastes in biological ditches.

Elaboration of the biological method for treatment of wastes from sulphite cellulose productions.

Elaboration of the biological high-duty activated sludge process for treatment of wastes from dairies in the biological ditches characterized by low costs of construction and simple operation.

Great importance is attached to the exchange of experience in this field with other countries. One of the most efficient means of establishing such exchanges is meetings of specialists which enable the mutual presentation of scientific and technical achievements and discussions of existing problems.

WATER POLLUTION CONTROL

NEW DIRECTIONS FOR WATER POLLUTION CONTROL

By Daniel A. Okun
Head, Department of Environmental Sciences and Engineering
University of North Carolina at Chapel Hill

A concern for water pollution control is not of recent vintage, at least not in Europe. The renowned English poet, Samuel Taylor Coleridge, in his poem "Cologne", written more than one and a half centuries ago, characterized the Rhine River in words that are appropriate today.

> In Cologne, a town of monks and bones
> And pavements fanged with murderous stones,
> And rags and bags and hideous wenches,
> I counted two and seventy stenches
> All well defined, and several stinks!
> Ye Mumphs that reign o'er sewers and sinks,
> The River Rhine, it is well known,
> Doth wash your city of Cologne;
> But tell me, nymphs, what power divine
> Shall henceforth wash the river Rhine?

Engineers and scientists have for more than a century addressed themselves to the technology of water pollution control. Had they not, this congested continent would today be uninhabitable. However, population growth, increasing urbanization, increasing industrialization, and most significantly, increasing expectations for a better life, have focused public attention on the problems of water pollution control. Our response to society must include not only technological improvement, but also institutional change and innovation, innovations akin to those introduced in the Ruhr region at the turn of the century.

In the organization of the Ruhrverband, it was recognized that wastewater is a resource and out of necessity and economy it must be reused. This was accomplished in part through common ownership and operation of water and wastewater enterprises. If water quality management is to be effective, close cooperation between water resource and water pollution control authorities must now be institutionalized everywhere. Parochial and professional loyalties and interests should no longer dictate how problems of water quality management are handled.

National, state, and local governments cannot be encouraged to initiate joint water-wastewater endeavors if the appropriate professional organizations are not willing to provide some leadership. In many countries of Europe, as in the U.S., professional engineering organizations exist separately in the fields of water supply and water pollution control. In the U.S., most environmental engineers are members of both types of organizations and are expert in both fields. This is less common in Europe where water supply and water pollution control are quite separate endeavors. An effort must be made to merge these interests to demonstrate to society the commonality of water supply and water pollution control problems and that we will not let our traditions interfere with their efficient solution.

Regional Organization

Water supply and water pollution control have been characterized since their initiation as municipal responsibilities. This has begun to change because the economies of scale in construction and operation reveal the reasonableness of regional solutions. The regrouping of municipal water supplies in England (1) into fewer, larger systems, from 1300 to fewer than 300, and the regional water supply networks in the Netherlands, have demonstrated the effectiveness of this approach. However, this is not so common in the management of wastewaters. In an excellent review of regional management of wastewater utilities, some recent accomplishments in the U.S. are described (2). For example, in a county in upper New York State, thirty-four separate treatment facilities are being replaced by four large treatment plants, while in another instance, one plant is replacing seven existing smaller plants. However, this regionalization does not consider integration with water supply facilities nor does there appear to be any incentive for such integration.

Regionalization of water supply systems with wastewater collection and disposal facilities into larger regional water resource management systems is a must for the future. Such arrangements would help avoid the many instances where one community's wastewater becomes the source of water supply for another community downstream. Larger size facilities would make possible the employment of qualified managers, engineers, and laboratory personnel in common enterprise to assure the region of high-quality water and efficient water supply and wastewater disposal service at lowest cost without objectionable impact on the environment.

Such regionalization would undoubtedly threaten the sovereignty of many municipal organizations and the positions of many individuals. However, the need for personnel will continue to grow and qualified individuals will always have a place for productive employment regardless of the institutional arrangement.

At both the government regulatory level, as well as at the local operating level, the water pollution control agency is generally separated from the agency responsible for water supply. At federal level in the U.S. they were once together in the Public Health Service, then they were separated, and as of a few months ago they are together again, with air pollution, solid wastes, radiation and pesticide control in the new Environmental Protection Agency. At the local level, separation is still the general rule.

Reuse of Wastewaters for Water Supply

Joint enterprise in water supply and wastewater disposal does not imply that wastewater need be or should be used for potable supplies although this is the common inference when reuse is mentioned. As Hansen has pointed out, the U.S. Public Health Service Drinking Water Standards state: "The water supply should be obtained from the most desirable source which is feasible, and effort should be made to prevent or control pollution of the source" (3). The same philosophy is embodied in the WHO Drinking Water Standards.

In assessing the quality of drinking water supplies we have far too long depended upon bacteriological quality, and had to a limited extent on chemical quality, and have neglected the precept that the water should originate from a protected and high-quality source if at all feasible. We would be distraught if we believed that our milk came from diseased cattle living in filthy barns even though we know that dairies have the technology to pasteurize the milk adequately.

Accepting highly polluted waters or wastewaters as sources of drinking water supplies may have been acceptable sixty years ago when the only contaminants of concern were bacterial pathogens and we were certain that treatment and disinfection would assure their destruction. However, today the quality problems of water supply are no longer so easily managed. The destruction of viruses is uncertain and the large number of chemicals emanating from modern industrial operations are little reduced and certainly not eliminated in conventional wastewater and water treatment practice. Treatment plants are not likely, in any reasonable time in the future, to be designed for removal of these chemicals, some of which are carcinogenic, mutagenic and/or teratogenic (4).

Public Health Service Drinking Water Standards do not apply to the direct reuse of reclaimed wastewaters for drinking, because (1) the potential for toxic substances is high and variable, (2) fail-safe devices have not yet been developed, and (3) the monitoring for these low levels of toxic substances is not adequate for quality control (3).

In California, where water is severely limited, officials have stated that "...the economics of treatment, quality control, monitoring and assured safe operation presently preclude the production of a suitable water from wastewater for certain purposes where quality requirements are high", and therefore no standards have been established for the direct reuse of wastewaters for domestic purposes although standards for the reuse of wastewaters for non-potable purposes have been established (5).

A proposal by the Public Health Service in 1965 to augment New York City's water supply which comes from well-protected upland impounding reservoirs, by adding reclaimed wastewaters directly to the distribution system has apparently passed into limbo. In that report it was stated that the augmented supply would meet or exceed every requirement of the Public Health Service Drinking Water Standards and would be a completely safe, reliable and aesthetically acceptable supply. The author of this proposal had given no attention to the potentially toxic chemicals that are inevitably present in the wastewaters from a major urban area. The current Drinking Water Standards do not address themselves to the presence of specific organic chemicals that have potential for toxic effect when very large populations are exposed to them continuously.

Although this proposal to augment New York City's water supply with its own wastewaters has not been revived, there is a revival--as there has been many times before--of the proposal that additional water supply for New York, to augment the high-quality upland source, be obtained from the Hudson River, the drain for much of industrialized New York State. This selection among alternatives, a more-expensive high quality source versus a cheaper poor quality source, is one that many cities are faced with.

Even in Germany where water resources are extremely limited, particularly in the industrial regions of the country, it has been agreed that because of both health and psychological problems "wastewater cannot be used directly for drinking and other domestic purposes" (6). In Germany, filtration, dilution and time in underground percolation and storage have been used for many years to help render a polluted surface water acceptable. Accordingly, direct surface waters provide only 9% of the total municipal supply in Germany while 26% is taken from surface sources via percolation and passage for from 40 to 100 days in the ground.

In Britain, "...the direct recycling of sewage effluent is not considered desirable because of the possible intensification of risk to public health" (7). There, the reclamation of treatment plant effluents for industrial use is receiving high priority.

To cite the one well-known instance in the United States where, for several months as an emergency measure, wastewaters were recycled for water supply, in Chanute, Kansas, according to Haney, "The public accepted the situation but rejected the water" (8).

A Scientific Group of the World Health Organization, in its evaluation of direct reuse of wastewaters for human consumption, pointed out that "...not enough is known of the long-term effect of certain of the trace chemicals found in wastewater, and there is still much to be learned concerning the removal of the more persistent forms of microbiological pollution such as some of the enteroviruses" (9).

If there is not to be direct use of wastewaters for domestic water supply what is the prospect for water reclamation in urban areas that are rapidly exhausting their current supplies of high-quality fresh water? These wastewaters can be used directly for purposes that do not require the high quality that is necessary when the water is to be used for drinking. Every urban center has within it and in its immediate environs many water needs that can be met with water of lesser quality, such as industrial use for process and cooling, irrigation, large-scale cleansing operations such as for streets and automobiles, recreation and the creation of aesthetically pleasing water bodies in recreational areas.

To the extent that high-quality drinking waters are now used for any of these purposes, and this amounts to virtually all urban irrigation, industrial process use and cleansing, to that extent are scarce fresh water resources being squandered. In only very few instances, where fresh water has been in extremely short supply and its value high, has there been any planned attempt to utilize reclaimed wastewaters for these purposes even though the precedent was established decades ago in Baltimore where its treated wastewaters have been purchased by the Bethlehem Steel Company.

However, it is good to know that the situation is rapidly changing. The City of Los Angeles has studied the use of reclaimed water for ground water recharge, for the prevention of sea water intrusion, for irrigation, for the creation of recreational and ornamental lakes, and for industrial water supply for oil refinery process water and cooling.

The City of Pomona Water Department is distributing reclaimed wastewater from the Los Angeles County Sanitation District for agricultural irrigation, including citrus and walnut grove irrigation, highway landscaping, and highway construction.

An unheralded but most appropriate development has been that at Colorado Springs, where about one third of the biologically treated wastewaters is given rapid sand filtration on mixed-media filters, disinfected and then stored and distributed through an extensive second distribution system for sale as irrigation water to college campuses, cemeteries, golf courses, and other large users. Part of this reclaimed wastewater is given lime coagulation and sedimentation for phosphate removal and then passed through rapid sand filters and carbon beds for removal of organic chemicals, and sold as industrial water. Supply of the reclaimed wastewater is limited to customers using more than 10,000 gallons (38,000 liters) per day.

The reclaimed wastewater sells for only 2/3 the price of potable water. By 1980, 90% of Colorado Springs wastewaters are expected to be reclaimed, putting off major investments that would otherwise be required for additional water supply to be obtained by tunneling through the continental divide.

A discriminating pricing policy can encourage the use of reclaimed wastewaters, with a high unit price for high-quality potable waters, and a lower price for reclaimed wastewaters. Something along this line has been suggested in the Soviet Union, where 43 per cent of the pure high-quality water supplied to Russian cities is used by industries that do not require water of drinking water quality. It is proposed to price this pure water beyond the reach of those who use such waters for industrial purposes.

Wastewater Reuse for Public Water Supplies

Utilization of reclaimed wastewaters for industry, agricultural irrigation, and for recharge has a long way to go before their full potentials are realized. However, when all such needs are met, or in situations where industrial, agricultural and recharge opportunities are not available, as in strictly residential communities in metropolitan areas, another alternative may very well become attractive. This is the utilization of reclaimed wastewaters for municipal uses that do not require water of a high quality, such as for household and urban watering, for cleansing, and for toilet flushing. Dual water supplies had been proposed earlier (10), (4). The image that is created by a proposal for a dual water supply is the extensive requirement for a second water system and the high costs that result therefrom, as well as the possibilities of cross-connections. However, when we recognize the order of magnitude of present and future housing programs, with their high population densities in multi-family structures of all sorts, the prospects for what might be considered an "industrial housing water supply" for non-potable purposes do not appear to be much different from those for providing a reclaimed wastewater supply for any other industry. The design of modern urban centers is little different from the design of industrial facilities, with service corridors and shafts that permit carrying many utilities readily to a wide number of users in a relatively small space. The provision of two water supplies in such settings is not any more incongruous than two or more supplies for an industrial complex, or separate sanitary and storm sewers.

One objection to such dual supplies is the danger of cross-connections, or of accidental drinking from the lower class system. Adequate disinfection would assure that inadvertent use would not lead to infectious disease. An accidental ingestion of the chemical contaminants in the second supply, at the concentrations that are likely to be present in wastewaters, would not be harmful. It is the lifelong ingestion of chemicals from polluted waters, chemicals not removed in conventional water treatment, that is potentially dangerous.

The Application of Reclaimed Wastewaters to the Soil

Following the first public outcry against pollution in London in the mid-nineteenth century, the solution was the application of London's wastewater to the soil for treatment and disposal. Although the "sewage farm" has fallen into disfavor, the application of reclaimed wastewaters for irrigation as well as wastewater disposal is once again finding a place. Water supply costs will be increasing substantially in the future, and the need for water will be matched by the need for fertilizer. At current prices for ammonium nitrate, triple superphosphate and potassium chloride, the value of the nutrients in reclaimed wastewaters amounts to some 5.5 cents per thousand gallons (3800 liters) not including the value of the water (11).

The assimilative capacity of soils for wastewaters is only now beginning to be studied intensively. The U.S. National Academy of Science has pointed out that "...(Soil) has a great capacity for receiving and decomposing wastes and pollutants of many kinds" (12). The assimilative capacity of soils for the decontamination of wastewater results from filtration, biodegradation, and physical and chemical absorption (13). The assimilative capacity is a function of the chemical character of the wastewater, the character of the soil, and the nature of the soil-wastewater reactions. Soils must be examined in the future for their assimilative capacity just as receiving waters were assessed for their assimilative capacity, although the establishment of parameters for the assimilative capacity of soils is far more difficult. In the case of soils, the wide variations in soil characteristics, not only from place to place but within a specific area, the non-isotropism and the heterogeneous character of most soils make it mandatory that each situation be studied intensively before any large-scale program of application of wastewater to the soil is undertaken. Hopefully, as information is gathered from widely varying situations, useful guidelines for wastewater disposal by land application may be developed.

However, rates of application that can be attained even under the best of circumstances with the most assimilative soils and the highest level of wastewater treatment are such that land disposal is only likely to be appropriate in certain locations, generally where suitable land is available. Where population densities are high, only relatively small portions of the total wastewater could be applied to the soil. However, even minor efforts at recharge with wastewater may help redress the growing loss of ground water resulting from urbanization, where permeable fields give way to impermeable membranes of asphalt and concrete.

Characterization of Wastewaters

Regardless of how successful we may be in consigning polluted waters and wastewaters to second class non-potable uses, a substantial portion of the population will be obliged to use polluted waters for their potable supplies for years and even generations into the future. The simplistic characterization of wastewater quality by means of BOD, COD, and even TOC is no longer adequate where wastes find their way into drinking water supplies. Treatment plants, whether for wastewater or for water supply, are not adequate to remove or even substantially reduce the concentration of most organic chemicals and their metabolites or the heavy metals that are likely to be of concern. Studies in England revealed that wastewaters from municipalities contained two well-established carcinogens, 2, 4-benzpyrene and 1,2-benzanthracene. These chemicals have also been identified at concentrations greater than 700 micrograms per cubic meter in samples from the Rhine River which is extensively used as a water source in Germany and the Netherlands (14).

If we are not to be continuously surprised by so-called "new" pollution problems such as arose with pesticides and mercury, surprises that almost inevitably result in hasty, ill-considered legislative and regulatory responses, we must ourselves initiate programs of surveillance that will anticipate problems. This must be handled from at least two widely disparate vantage points:

(1) Intensive water quality surveillance programs must be instituted in an attempt to identify and quantify all suspected contaminants in water. A protocol for examination needs to be developed and more sophisticated tools are required both for the concentration of these trace chemicals and for their analysis. The carbon chloroform extract is entirely inadequate for the purpose, as it misses an unknown portion of wastes that are not absorbed on the carbon column and because the analysis of the absorbed material is not well structured. Another approach that should be investigated is the use of selective membranes in series or in parallel to concentrate contaminants, a procedure which would help assure that no chemicals of likely significance would escape the analytical process. After the contaminants are concentrated, the increasingly sophisticated tools of modern analytical chemistry must be used so that analyses can be made routine and reproducible.

Data must be amenable to continuous recording on computer tape so that sudden changes in quality are detected and so that the masses of data can be analyzed for trends in water quality improvement or deterioration.

(2) Comprehensive "sanitary surveys" must be conducted. Because of the very large number of chemicals that may be in a major river that serves as a water supply, it is virtually impossible to attack a water sample with any confidence that all potential contaminants can be identified, unless there is prior knowledge of the materials that are discharged to the water in the first place. What in the early days of water quality management was called the "sanitary survey" must now constitute a comprehensive materials balance so that all materials coming into the watershed can be measured and their disposition determined. This would give presumptive evidence of the contaminants likely to be present and would be a guide to the analyst as to what he should be seeking in his analytical water examination. Without knowing what we are looking for it would be impossible to detect the presence of many troublesome constituents, much less to design facilities for their removal.

Such surveys of materials that enter into industrial processing do threaten the confidential nature of industrial enterprise, but there is no alternative. Arrangements must be made for administrative protection for industry, in much the way that tax agencies provide secrecy for proprietary information.

Chemical Treatment

Until high degrees of treatment than can be accomplished by conventional biological treatment are required, and this is now beginning to be the case, there has been no incentive for developing the more sophisticated chemical processes that would be expected to remove specific contaminants. Modern biological processes are relatively inexpensive, and it is not likely that new sophisticated chemical processes will replace them for the bulk of the waste treatment that needs to be accomplished. However, in those instances where specific contaminants, be they toxic substances or nutrients, need to be removed, chemical treatment offers new opportunities. These chemicals include not only the conventional coagulants and conditioners, but also pure oxygen, oxidants such as bromine and ozone in addition to chlorine, and a wide range of organic chemicals many of which may be designed for specific uses in water or wastewater treatment. Others in this seminar are discussing new technological approaches to wastewater treatment.

Treatment in Sewerage Systems

The increasing use of certain chemicals may make attractive what has been a long-neglected opportunity to utilize existing facilities for improved wastewater treatment, namely, treatment in the conveying conduits of the sewerage system. At a velocity of two feet (0.6 meters) per second, one kilometer of sewer provides a detention period of almost half an hour. A system would not need to be large to provide detention within the sewerage system of the same order or magnitude as the detention in the treatment plant itself. Some imagination might very well go into encouraging stabilization or treatment of the wastes within the system. One small step in this direction has been the proposal that additives might increase the carrying capacity of the sewers (15). The addition of 40 to 60 milligrams per liter of a chemical additive increased the flow-carrying capacity of a sewer by 80 per cent, while 100 milligrams per liter increased the flow 110 per cent. Ancillary benefits allegedly included up to 40 per cent increase in sedimentation efficiency and improved dewatering qualities of the sludge as the dosage of additive was increased. While no cost data are yet available, the possibilities seem interesting indeed, particularly where long lines would reduce unit costs of the chemicals.

The addition of nitrous oxide gases at the head end of a sewer system has been claimed to reduce the BOD of the treatment plant influent substantially as well as helping to reduce grease collections in the sewer system and avoiding septicity.

The possibilities for treatment within a sewer system have not really begun to be explored. They include not only chemical treatment, but biological treatment as well. Air or oxygen might be introduced into the larger intercepting and truck sewers, or biological floc might be recirculated or affixed to media in the conduit. Sewers of the future might be enlarged to provide surfaces for biological growths without interfering with flow capacity. The additional cost might be small compared to that required to accomplish the same degree of treatment at the plant. Similar efforts might be appropriate in the wet wells of pumping stations, which are now used only as flow regulators.

Pressure Conduits

Extensive studies have been made of the feasibility of using pressure sewers to replace conventional gravity sanitary sewers (16). In typical urban areas, pressure systems have been estimated to be costlier than conventional sewer systems, mainly because of the costs of grinders and pumps required for individual households in the system. In only one instance, to this writer's knowledge, has a pressure system been used, and this because of special topographical conditions (17).

Again, while it may be too adventuresome to introduce so major a change in sewerage system design throughout an existing community, pressure sewers would appear to be entirely justified and likely to be economically feasible for new systems serving densely populated buildings whether they are hotels, multi-family housing units, office buildings or commercial complexes such as shopping centers. In such circumstances, the pumps required for a pressure system, and even the provision of standby power, would not be unreasonable, and a substantial saving would accrue from the use of smaller size sewers and the relaxation of grade construction.

Adoption of pressure sewers would be appropriate in sprawling metropolitan areas with new densely populated satellite communities, particularly where the terrain is flat or where the topography and the land use plans are not hospitable to gravity sewers. Of course, pumping stations and force mains are now widely used in sewerage systems, but they are incorporated only as a reluctant alternative to gravity flow rather than as a studied part of an overall design. With the rapid improvement in pumping technology and the relative lowering in power costs as compared with construction costs, the utilization of pumping and smaller-diameter force mains will become increasingly attractive as an alternative to larger size gravity conduits. And in the provision of utilities for cities of the future, the pressure sewer will be much more compatible with the utility tunnel, or utilidor, than the gravity sanitary sewer.

Manpower and Womanpower

Wastewater treatment facilities at present are recognized to be inadequate both in their number and in the degree of treatment they provide. Even under these circumstances, the personnel required to operate these facilities is insufficient and largely inadequate in competence to meet current requirements. It has been demonstrated that the revenues per unit of capital investment in the water and wastewater field are far below those for the other utilities (18). Payment for wastewater facility operating personnel is far below that for other utilities. Accordingly, many wastewater treatment plants, particularly those serving medium and small size communities, are operating far below their intended efficiencies because of the lack of qualified supervision and also because of insufficient regulatory control. A facility may be visited only once every few years by regulatory officials and even where reports are required regularly, the manpower in the headquarters or the regional offices of the regulatory organizations is insufficient to review their content. We will need an order of magnitude increase in manpower, nor should we forget womanpower, if an appropriate benefit from the increasing capital investment in water pollution control is to be obtained.

However, in the U.S. the portents are not good. The number of students entering engineering is not keeping pace with increased population. In 1965, only 9.5 per cent of college men were engineering students as compared with 13.7 per cent in 1955 (19). Men's interest in engineering has been declining, and women have not shown any increase in interest. While only three of 100 engineers in the United States are women, the figure in the Soviet Union is more than 30 per 100. In the USSR, the enrollment of women in engineering schools is more than double the total enrollment of men and women in engineering schools in the United States. (The number of women participating in these seminars in Warsaw and Bucharest is encouraging).

Even when likely candidates are found in the engineering schools, a good many of those who go on to practice have not had the graduate study which provides the special competence required for the field of water pollution control. The increasing generalization of undergraduate curricula requires that, if an individual is to be properly prepared, he or she must plan to go on the specialized graduate study. Some 85 per cent of practicing engineers surveyed in the U.S. felt that they should have taken graduate study. The National Council of Engineering Examiners is recommending that one year of graduate study be a requirement for licensing in the future. Of all specialties in engineering, except for nuclear engineering, a larger percentage of sanitary or environmental engineers in the U.S. has completed the master's degree than any other specialty in engineering. However, the total number is still small.

In Western Europe, the preparation of specialized environmental engineers is far less extensive than in the U.S. The well-known European Course in Sanitary Engineering at the Technological University in Delft, and the few well-known institutions such as those at Stuttgart, Zurich, Naples, and Vienna prepare far too few engineers to meet the needs of growing programs of water quality management. The situation in Eastern Europe is far better, but still not adequate. And the training of specialized technicians for plant operation, and for water monitoring is entirely unsatisfactory. The World Health Organization has taken some initiative in education, but this is only a beginning (20).

The situation is not bleak, however; with the increasing interest in the quality of the environment, and the growing commitment on the part of young people towards devoting their lives to socially useful pursuits as contrasted with simply materialistic objectives, the opportunity for increased recruitment to work in the field of water quality management is great. We have seen this in the numbers and in the quality of those applying for graduate study in the Department of Environmental Sciences and Engineering at the University of North Carolina, and I am confident that the same situation prevails at other educational institutions. It behooves us to build upon this newly developed interest to make prospective engineers aware of the opportunities in this field, and to increase the resources for specialized education and training.

With industry's growing responsibility in water quality management both in solving their own pollution problems and in providing the hardware for water pollution control generally, industrial organizations should sponsor training for their own personnel and assist educational institutions with their programs.

The ultimate hope for the changes that represent the appropriate response to societal needs rests with our young engineers and scientists, and we must encourage them.

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NEW TECHNOLOGY FOR WATER POLLUTION CONTROL

By David G. Stephan, Assistant Commissioner
and
John J. Convery, Special Technical Assistant
Research and Development
Water Quality Office
Environmental Protection Agency
Washington, D.C. USA

If the decade of the seventies is truly to be the "Age of Aquarius," it must be a decade of action to control and prevent water pollution and to restore the quality of the waters of the world. President Nixon has recommended that the United States spend $12 billion for the construction of municipal pollution control facilities during the next several years with a re-evaluation of the resource requirements to be made in 1973. The costs involved in controlling all sources of water pollution, municipal, industrial, agricultural, mining and other sources, have been estimated to be on the order of $60 billion in the United States. While these sound like, and in fact are, tremendous investments, they represent, in perspective, capital expenditures of only some $60 per capita for municipal sources and about $300 per capita for all sources put together. These investments would also be spread over a number of years. These costs can, and, in fact, should be compared with the current per capita investments in other utilities such as gas ($125/capita), phone ($310/capita), electric ($433/capita) and in federal highways ($618/capita).

A national commitment of this magnitude and an international commitment of significantly greater magnitude present a unique new challenge to individuals involved in environmental quality control and particularly in research. The challenge is to go one step further and not just do research, but actively promulgate research findings to the users of this technology--and, moreover, not just promulgate isolated research results of limited scope but to transfer complete "packages of technology" to the user community. Packaged technology would include an array of process alternatives available for treating a specific waste, cost and performance information on the total wastewater treatment system, including consideration of the ultimate disposal of brines and sludges, operating requirements and design guidelines. The most cost-effective technological developments possible for application in the immediate and near-term future must be identified.

In October of 1970 a special program was announced in the United States to transfer, not just disseminate, the results of research to the potential users of new pollution control technology. This "technology transer program" is designed to demonstrate convincingly the technical and economic practicability and the reliability of research findings. The audience is composed of both the technician, i.e., the design engineer, the treatment plant operator, etc., and the non-technician decision-maker, i.e., the mayor, the legislator, the regulatory official, etc. Our objective is to insure that the latest techniques are incorporated into the design of treatment and control facilities which will be constructed in the next several years. The technology transfer program utilizes a variety of communications techniques: large presentations for general audiences, technical seminars for federal, state and local officials, design workshops for small groups of consulting engineers, publication of design manuals, use of filmstrips and video tape presentations plus tours and lectures at demonstration facilities across the country where advanced waste treatment and pollution control methods are in full-scale operation. Primary emphasis is currently being given to the municipal sewered waste problem since this is the area where the greatest "Action-Effectiveness" (i.e., a qualitative assessment of pollution problem areas which combines the relative cost of control, accomplishment in meeting standards, availability of technology and willingness and ability to proceed) can be achieved.

Municipal Wastewaters

Municipal wastes include combined domestic and industrial wastewater discharges which characteristically are a large source of degradable organic material, bacteria and viruses and which contain nutrients that accelerate eutrophication of lakes and estuaries. Major emphasis in this area has been directed toward demonstration of lower cost and more efficient methods of removing organics, phosphorus and nitrogen.

More than a dozen chemical treatment systems for the removal of phosphorus as well as BOD and suspended solids are available today for full-scale application. System alternatives include the choice of chemical coagulant (iron, alum or lime) and the point of chemical addition (to primary, secondary or tertiary processes). Factors affecting the choice of chemical and point of addition are influent phosphorus level, effluent discharge requirement, wastewater characteristics such as alkalinity and pH, plant size, local cost of chemicals, sludge handling facilities, ultimate disposal alternatives and the conventional process utilized. Generally, a system utilizing iron or alum added before the primary clarifiers or aerators is selected where an effluent requirement of I-2 mgle phosphorous is desired and the influent phosphorus concentration is low to moderate (I0 MG/L) (Figures 1 and 2). An effluent phosphorus concentration of 0.5 MG/L can be achieved if a supplemental dose of coagulant is added prior to a tertiary filtration step. Total operating costs for chemical addition to the primary or secondary step, including amortization of the chemical feeders and expanded sludge handling equipment, will be $0.06-$.08/1000 Gal. In some locations, iron salts are available very cheaply as waste pickle liquor; a substantial reduction in chemical costs can be achieved if a reliable source of waste pickle liquor is available (Table I and Figure 3).

Lime treatment of raw sewage or secondary effluent would often be utilized in larger plants (10 MGD) where the economies of scale are significant and recalcination is economically practicable. Lime treatment is particularly advantageous when the influent alkalinity is low and the influent phosphorus concentration is high. Effluent phosphorus concentrations of 0.5 MG/L are attainable without filtration and 0.05 MG/L can be achieved with filtration. Total operating cost, including amortization of the capital investment, for a 10-MGD two-stage lime clarification system is about $0.09/1000 Gal.

A novel chemical treatment system which has recently been demonstrated is the moving bed filter (MBF). The filter media, sand, is mechanically pulsed countercurrent to the direction of flow. The accumulated solids and the sand are mechanically guillotined at the filter surface, washed to separate the filtered solids and the sand is recycled to the base of the filter. The removed solids are gravity thickened and can be dewatered in a rotary precoat filter. MBF has been successfully applied to alum-coagulate secondary effluent, unsettled trickling filter effluent, primary effluent and even raw sewage. (Figure 4) The filter is capable of handling high and variable suspended solids loads on a continuous basis. A 5-MGD plant in Manville, New Jersey, using the MBF with alum coagulation is in operation to significantly up-grade the trickling filter effluent quality and achieve 95% phosphorus removal (Table II). Additional development work is being conducted to evaluate the concept of a single unit physical-chemical system using the MBF and powdered activated carbon.

The Environmental Protection Agency has contracted for the preparation of a design manual which will present, in one document, design guidelines and cost information on all the alternative phosphorus removal techniques currently available.

How extensively is chemical treatment being applied in the United States? A partial list of full-scale plants utilizing chemical treatment is shown in Table III.

The total operating costs reported for chemical treatment cannot be attibuted entirely to phosphorus removal since a substantial improvement in the removal of organics and suspended solids is achieved simultaneously. Chemical clarification of raw wastewater will remove from 70-80% of the organics and 90-95% of the suspended solids (Figures 5 and 6). These results have stimulated a great deal of interest in the concept of independent physical-chemical (IPC) treatment utilizing chemical clarification and granular carbon adsorption. IPC treatment is capable of removing 95-98% of the organics from municipal wastewater (Table IV). The product, containing 6-12 MG/L of total organic carbon, is suitable for reuse as a high quality irrigation supply, industrial supply or perhaps, even for body-contact recreational purposes. The total operating costs for a 10-MGD IPC treatment facility are estimated to be $0.22/1000 Gal. which compares favorably with the cost of a conventional secondary treatment plant with phosphorus removal. Moreover, IPC treatment offers several distinct advantages over conventional primary and secondary treatment:

Reduced land requirement--1/4 to 1/2 of land area for conventional treatment.

Greater flexibility in design and operation.

Reduced sensitivity to diurnal flow and load variations.

Immunity to substances toxic to biological systesm.

A design manual on granular activated carbon adsorption presents process design guidelines, cost and performance information and discusses equipment considerations of interest to the design engineer such as mode of contacting (upflow, downflow, static bed, fluidized bed), materials of construction (concrete, steel), and mode of operation (gravity, pressure).

A list of full-scale plants which will be using independent physical-chemical treatment is shown in Table V.

Nitrogen removal capability can be incorporated into the treatment scheme of a physical-chemical plant by utilizing one of the recently-developed ammonia removal techniques such as breakpoint chlorination, or ammonia air stripping at elevated pH. The largest demonstrated nitrogen removal plant in the United States is the 3.5 MGD, cross-flow ammonia stripping tower at Lake Tahce, California (Figure 7). Air stripping, when used in conjunction with lime precipitation of phosphates, is a relatively inexpensive physical-chemical ammonia removal technique which requires a capital investment of only about $700,000 for a 10-MGD facility. Total oerating costs for a 10-MGD plant are approximately $0.04/1000 Gal. Because large air flows (200-400 ft^3/Gal) are required, the process is temperature-sensitive and freezing is an operational constraint limiting process application to warmer climates. In addition, the process not without operating difficulties because of the formation of calcium carbonate scale.

Breakpoint chlorination is also a broadly-applicable alternative. This technique can produce an effluent with 0.5 MG/L of NH_3-N from a feed concentration of 20 MG/L NH_3-N at a cost of $0.04/1000 Gal. (assuming chlorine at 3¢/lb). The technique will increase the total dissolved solids in the effluent, primarily chloride ion (7.6 parts CL/Part NH_3-N) but will oxidize the bulk of the NH_3 to N_2 which does not represent a potential air pollution problem.

The recent successful demonstration, at 2.5 MGD, of using high purity oxygen in the activated sludge process has the potential to significantly extend the utility of the current investment in activated sludge facilities and reduce the capital requirement for future plants of this type (Figure 8 and Table VI). A conventional 10-MGD activated sludge plant will cost some $0.135/1000 Gal. to operate, including capital amortization. Cost reductions of 15% or more appear to be attainable for new plants utilizing oxygen. Percent savings are portentially greater for conversion of existing overloaded plants to oxygen. These cost savings are attributable to the reduced detention time required for the oxygen system to achieve BOD removal. In full-scale tests, for example, the oxygen system has achieved a 92% reduction in BOD in a detention time of 2 hours compared to the 6 hours required by a conventional diffused air system.

A list of full-scale plants which are being designed for oxygen aeration is shown in Table VII.

Nitrogen removal can also be incorporated into a treatment scheme based on biological processes. A three-stage biological system has been developed which provides excellent process control for the attainment of high efficiency removal of carbon and nitrogen. This system, if augmented with chemical addition to the aerator, can provide control of both phosphorus and nitrogen nutrients (Figures 9 and 10; Table VIII).

Carbonaceous materials are oxidized in the first stage followed by nitrification of the ammonia in the second stage and denitrification in the third stage, a carbon source, such as methanol, is required for the third-stage denitrification. Over-all nitrogen removal efficiencies of 90% are obtainable. The incremental cost for achieving nitrification in a 10-MGD facility is between 3¢ and 4¢/1000 Gal. and, for denitrification, between 4¢ and 5¢/1000 Gal. Five full-scale demonstrations of this technology, at plant flows as high as 25 MGD, are expected to be initiated next year.

While much new process technology has been developed for municipal pollution control applications, these same techniques are finding application in the areas of industrial, agricultural and mining pollution control.

Industrial Wastes

Industrial wastes are, of course, highly diverse in nature. Industrial waste components include acids, alkalies, salts, nutrients, toxic materials, organic and inorganic solids, oil and grease and even heat. Even with regard to BOD, however, in the United States industrial wastes represent a greater BOD load than do all municipal wastes combined. the BOD_5 population equivalent for U.S. industrial sources exceeds that of 400 million people.

We are seeking to develop and demonstrate better methods of treatment and control for wastes from industry. Part of this goal, and a part of ever-increasing importance, is to develop closed-loop systems for recovery and reuse of the water in individual industrial processes or in industrial complexes.

Under its industrial pollution control research program, the Environmental Protection Agency assumes part of the risk of developing new technology and promotes and demonstrates improved methods for industrial pollution control through a program of grants direct to industry. There are over 170 completed or on-going projects in this EPA industrial waste control demonstration program. It is beyond the scope of this paper to discuss progress in all of the industrial categories. Highlights of major accomplishments are presented.

When a beneficial use for waste pickle liquor, such as utilizing it for phosphorus precipitation from municipal wastes, is not economically practicable, the waste can, nonetheless, be treated economically. A technique for treating the acid rinse waters produced by the HCL pickling of steel strip preparatory to cold rolling has been successfully demonstrated at a scale of 2.2 MGD. The acid rinse waters are neutralized by limestone and the ferrous iron is then oxidized to ferric iron in aeration tanks (Figure 11). Polyelectrolytes are used to facilitate the sedimentation of the ferric hydroxide floc. The effluent from such a system is clear and of neutral pH but it still contains high levels of chloride (perhaps 1,000 MG/L). The settled solids from the sedimentation step can be dewatered on a vacuum filter and disposed of by land fill. This treatment system costs about $0.20/1000 Gal. or less than $0.05 per ton of steel. This system should find increasing application in the United States in view of the trend of the steel industry to convert to HCL pickling.

One of the most widespread and intractable problems of the chemical industry is phenolic wastes. Phenol is a serious problem because of its widespread occurrence, toxicity to many biological species and the waste it can impart to fish and other seafood. For the chlorobenzene process for the manufacture of phenols, a unique, closed-loop system for treating and recovering phenolic wastes has been demonstrated at one quarter of full-scale (Figure 12). The effluent from the phenol production facility is passed through a steam stripper to recover benzene and acetone and is then cooled in a heat exchanger before being applied to two activated carbon adsorption columns in series. Phenol is removed in the first column from (15-200 MG/L down to 4 MG/L). The effluent is then acidified to a ph of 3 with HCL and then acetic acid is adsorbed on a second carbon column. Phenol and acetate are recovered from the carbon by chemical elutriation with caustic and are recycled for reuse. The effluent brine from the carbon columns is also recycled as a feed stock for chlorine cuastic production. Final phenol concentration in the return flow is as low as 0.1 MG/L.

Not all forms of pollution are as invisible to the eye as the toxic effects of phenols. Some pollutants, such as color bodies are much more visually evident and are aesthetically unacceptable. Kraft pulping and paper making produce effluents with as much as 1,400 platinum cobalt units of color. Lime clarification of this effluent can achieve and 85-90% reduction in color at a cost of about 36¢/1000 Gal. (Figure 13). This is equivalent to around $4 per ton of pulp processed. This cost could be significantly reduced if a system of recalcination, similar to that used to recover and reuse lime-phosphate sludges from municipal treatment plants, were developed. Developmental efforts are now underway.

The development of alternative methods of sludge disposal is an essential ingredient to providing "packaged technology." Some recent and interesting applications of sludge recovery and reuse concepts have been developed. The primary sludge from a pulp and paper mill plant, for example, can be dewatered on a pressure drum filter (technology borrowed from Europe) and used as (1) a supplemental fuel ("hog fuel") for conventional steam boilers, (2) a dry mulching material for highway slopes, or (3) an agricultural soil conditioner (Figure 14). In the food processing area, the peel, seeds and low-grade molasses wastes from a citrus juice concentrating plant can be dried, pelletized and sold for as much as $80/ton as a cattle feed supplement. Moreover, the waste activated sludge from the biological treatment plant at this location is being dried and sold at $240/ton as a chicken feed supplement which is high in protein and vitamin B-12. The revenues from the sale of these "by-products" are more than adequate to cover the cost of the entire wastewater treatment plant. The demonstration plant at Winter Garden, Florida, is being expanded to meet the increasing demand for these "by-products" which has been generated by the local farmers.

The disposal of sludge from an API separator (a unit developed by the American Petroleum Institute), tank bottom sludge and spent caustic has always been a serious problem in the petroleum industry. Pit storage, burial and open burning have been partial and, frankly, unsatisfactory solutions in the past. A 70-barrel/day fluid bed incineration system for the treatment of refinery chemicals and oil sludges has been successfully demonstrated. The facility is actually a modification of a commercially-available process which was originally designed to process sulfite wastes from the paper industry. At least three major oil companies in the United States are installing similar waste control facilities at several of their plant sites.

The methodology discussed so far has focused on "treatment" as the primary pollution abatement technique. Control of pollution at its source or control of water use are also important pollution abatement techniques. An excellent example of in-process control has recently been demonstrated in the canning industry. A dry, caustic peeling technique, capable of eliminating 90% of the water-use requirements and associated BOD from the peeling operation, has been demonstrated at full scale for potato processing and is now being evaluated for sweet potato and table beet processing. The potatoes are dipped in a lye bath and transported on a conveyor, at a controlled speed to regulate the penetration of lye, to an infrared gas-fired burner. The burner bakes the peel off and residual flakes of peel are cleaned by a series of rubber-tipped rollers. The potatoes are then given a minimum volume high-pressure rinse as a final polishing step. Such a dry caustic peeler costs approximately $98,000/Line (20,000 lbs/hr) compared to

$29,000/line for conventional peeling equipment. However, activated sludge treatment of potato wastes costs about $0.06/lb. BOD_5 removed and, based on the reduced hydraulic and BOD load to the treatment plant and the savings in caustic and operating costs for the peeling operation, the dry caustic peeler will pay for itself in less than four months. There are over 15 installations in the United States today using this technique with an additional 35 on order.

A modification of the dry caustic peeling technique which eliminates the infrared burner is being evaluated for the peeling of peaches, pears and apricots with the potential of reducing the water-use requirements by 95%.

Peeling is, of course, only one step in food processing. The other two major water-use steps are transport and blanching. We have demonstrated, at 8.6 MGD, the treatment, recovery and reuse of beet transport water and are now evaluating various types of steam, hot water, microwave and hot air pilot blanchers in an attempt to reduce the water-use requirements for this operation by 50% or more.

Agricultural Wastes

Agricultural pollution includes nutrients from fertilizer runoff, salts and pesticides from irrigation return flows and BOD and solids from confined animal feedlots. Feedlot wastes are of increasing concern in the United States. The BOD_5 from a confined animal production operation can range from 10,000-50,000 MG/L.

To a large degree, the management techniques of confined animal feeding have increased the severity of the pollution problem from these sources by concentrating the wastes in local areas. One important approach toward solving the animal feedlot problem involves the techniques of housing or arranging the animals in a manner which will minimize or eliminate the waste collection and transport problems. For example, a technique of caging hens and syspending them over an oxidation ditch has been demonstrated for a 250-hen operation (Figure 15). The wastes are biologically stabilized in the oxidation ditch prior to land disposal of the sludge. The operation is superior to the alternative of dry conveyor collection both in terms of odor control and of producing a stabilized sludge. The cost of the oxidation ditch treatment is between 1¢ and 4¢ per dozen eggs produced. An interesting observation has been that swine can be trained to walk over a separate slotted floor area to deposit their wastes directly into an oxidation ditch below (Figure 16). The judicious placement of their food supply directly across the slotted floor from the pen area provides the needed inducement. Unfortunately, cattle are not quite so cooperative. Open feed areas with tight soil and proper runoff collection facilities can, however, provide adequate control. Loose soil and poor drainage are not only undesirable from a waste management standpoint, but also from a beef production perspective. Cattle can lose 50% or more of their normal weight gain during the summer months by walking around in unconsolidated muddy soil. Several alternative collection systems are available for confined cattle feedlots. These include mechanical scrapers, slotted floors and sloped floors.

Biologically stabilized feedlot wastes can often be disposed of by land spreading the sludge and spray irrigating the effluent (Figure 17).

Where the size of the operation or the local soil conditions preclude use of land disposal, advanced waste treatment nutrient removal techniques, similar to those used for municipal pollution control, can be used prior to discharge. The nutrient concentration of animal feedlot wastes as for BOD_5, is significantly higher than municipal waste concentrations. For example, phosphorus concentrations as high as 110 MG/L AS P are not uncommon in poultry wastes. Chemical costs to achieve 80% phospherous removal from poultry wastes are $0.40 to $0.53 per 1000 Gal. for lime and alum respectively. Dosing requirements average almost 1100 MG/L for alum and 4,400 MG/L for lime. Lime treatment has the added advantage of providing superior color removal but increases the sludge handling requirements.

Irrigation return flows are another significant source of agricultural pollution. The increase in silt and total dissolved solids is significant but the increase in nitrates may often be of special importance because of potential health effects in drinking water supplies. At Firebaugh, California, denitrification of irrigation return flows, by adding methanol and passing the flow through a coarse media upflow contactor, has been successfully demonstrated. The nitrate concentration can be reduced from 25 MG/L to 2 MG/L. Application of this technique in the San Joaquin Drainage Basin, for example, would reduce the nitrate load to San Francisco Bay by 125,000 lbs per day. Denitrification technology utilized in municipal pollution control is similar.

Other Urban Wastes

The category, "Other Urban Wastes," includes storm and combined sewer discharges, urban runoff and unsewered municipal wastes. Other urban wastes have many of the same adverse effects on water quality and water use as municipal sewage. They contain high concentrations of bacteria, solids, organics and inorganics. The primary difference between these wastes and municipal sewered wastes is their frequency and unpredictability of occurrence and their variability in hydraulic load. Separation of storm and sanitary sewers, once thought to be the ultimate solution to the combined sewer problem, is of questionable applicability in many locations because of cost, physical disruption of normal urban activities during construction periods and the realization that even separated storm flows may have high pollution potential due to suspended solids, BOD and bacteria. One solution is to build optimized storm flow collection and treatment systems. Because of the intermittent nature and magnitude of flows typical of these wastes (1 to 100 times greater than dry weather flows), the utilization factor of capital invested in facilities will be less than for systems where waste flows approach steady-state conditions. Techniques which are relatively lows in capital cost, in spite of relatively high operating costs, are preferred for these applications. There is a real premium to be gained by using unit processes capable of high flow rates such as microstraining, fine screening, dissolved air flotation or high rate (20 GPM/FT^2) media filtration (Figure 18). For example, in Philadelphia, Pennsylvania, the potential utility of microstraining of combined sewer flows at 45 GPM/FT^2 was demonstrated. Microstrainers, rotary drum screens often used for algae removal in water treatment, have also been demonstrated to have real value for tertiary solids removal from treated municipal sewage. In fact, a 15-MGD facility is now under construction in Chicago, Illinois. Using a 23-micron screen, the suspended solids removal efficiency in this application has ranged from 62% to 96% and has averaged 80%. Volatile suspended solids removal averaged 71%. Estimates of the cost of microstraining and chlorination (5 to 20 PPM dose) of storm runoff are on the order of $9,000 per MGD or $11,000 per acre of drainage treated. This cost, while high, is only 40-50% of the estimated cost of separating storm and sanitary sewers which has been estimated to be $20,000-$23,000 per acre.

Fine screening (297 microns) and dissolved air flotation with alum and polymer coagulation of combined sewer overflows was demonstrated at 5 MGD in Milwaukee, Wisconsin. Reductions of up to 98% suspended solids, 79% BOD and 92% of the phosphorus concentrations in the wet weather flow were measured. The capital cost of this type of installation is about $12,000 per MGD of capacity (approximately $.01 per daily gallon) or $9,000-$14,000/acre. Operating costs are 3¢-4¢/1,000 gallons treated.

Control techniques are also a very vital part of abating pollution from storm and combined sewers. Control techniques include the physical aspects of routing, diversion and containment of either stormwater or combined sewage (Figure 19). In-line and off-line storage during storms with subsequent discharge to treatment facilities has merit and is an excellent way to improve the utilization factor of the capital investment in collection and treatment facilities. In Detroit, Michigan, a monitoring and remote control system is being demonstrated to maximize the storage capacity of the existing sewer system. New power-operated diversionary overflow structures and automatic control instrumentation have been installed to measure wastewater flow, quality, conduit liquid levels, and to control remotely diversion gate operations. Telemetering is provided to transmit and record data collected and to provide feed-back data relative to the status of the remotely controlled units.

Another possible solution to part of the non-sewered municipal waste problem is being demonstrated at Grandview Lake, Indiana, and Albany, New York. Individual grinder-pumps have been installed in each house. Wastes are then discharged into small diameter, plastic pressurized sewers (Figure 20). The sewage from a small group of houses is collected and treated in a package plant. This kind of system may be applicable where distantly-separated homes or rock excavation costs make the construction of conventional sewers prohibitively expensive.

Oil Spills

Oil spill problems are related primarily to transportation activities since adequate overflow channels, secondary diking and alarm systems can readily be designed to minimize spills from stationary facilities. During the last several years over 150 million gallons of oil have been released in major spill incidents costing tens of millions of dollars to clean up, and the potential insults to the environment from accidental spills are increasing as ships get larger (16,000-30,000 DWT tankers in the 1950's compared with 200,000-350,000 DWT tankers in the 1960's and 70's) and as pipelines which have served us well in the past are getting older and failing more frequently.

A great deal of research effort in the United States is currently being focused on methods of containment (booms), mechanical harvesting techniques (air, water, mechanical sweeps), pickup, separation and disposal methods.

A 30,000-Gal. per hr. oil skimming and separation system capable of producing a discharge water of less than 100 PPM and a recovered oil containing less than 5 percent water has been successfully demonstrated. The oil content of the discharge water could be reduced to less than 20 PPM if required by recycling it through the centrifuge a second time. The skimming device is a twin-hulled barge with a partially louvered bottom appropriately baffled to attenuate wave action. Skimmed oil is collected by a floating weir and pumped to a centrifuge (4,000G) capable of handling inlet emulsion concentrations up to 5,000 PPM (Figure 21). The over-all system efficiency is 99% when operating at 0.5 knots and 80% at 5 knots under smooth sea conditions. The system will operate under conditions up to and including sea state 4 (moderate waves, wind velocity 20 knots, wave height 5 ft.), but with some loss in efficiency. This system, together with booms and an oil storage tank, constitutes a complete ocean oil spill recovery system (Figure 22).

What can be done when an oil slick has already been washed on-shore and contaminated the beaches? Early attempts to clean contaminated beaches were often slow, tedious and expensive operations. A technique capable of cleaning 4.5 miles of contaminated beach in one working day has recently been demonstrated. The beauty of the operation is that the equipment, or suitable substitutes, is almost universally available for contingency spill clean-up operations. The equipment involves a grader, an elevating scraper and an imaginative systems approach (Figure 23). The operator of the grader (modified with half-tracks to improve traction in the sand) starts his first pass furthest inshore with the moldboard set at a 40 degree angle with respect to the direction of travel. The last pass is made at the surf line with the moldboard angle changed 100° to reverse the direction of cast from seaward to landward. The elevating scraper picks up the resulting windrow (material deposited from the trailing edge of the grader blade). The procedure can be used to clean sections of beach 200-300 yards at a time. This is an excellent example of utilizing commercially-available equipment and reminding us that pollution control techniques need not be unique or novel, just effective.

Another facet of the over-all pollution problem is the disposal of used motor oils. A system employing vacuum distillation and fractionation, capable of handling 9,000,000 gallons per year has been demonstrated during the last year and a half. The used crankcase oil provides No. 6 fuel oil (28.4%), No. 4 fuel oil (36.8%), No. 4 diesel oil (20.8%), No. 2 fuel oil (5.5%), gasoline additive (0.5%) and process fuel for plant use (5%). The remainder is water. The recovered products are supplemented with first grade materials at a cost of $0.003 to $0.24/Gal. to meet U.S. market specifications for products which have a retail price of $0.05 to $0.10/Gallon. Direct operating costs for the plant are $0.04/Gal.

Changes in the oil industry to multi-grade motor oils with much higher additive contents and the trend of automobile manufacturers to greatly increase the mileage and time intervals between recommended oil changes has significantly changed the composition of crankcase oil in recent years. Pretreatment steps of centrifugation, solvent extraction and chemical treatment will have to be incorporated to remove the spent and degraded additives, sludge and tar-forming materials produced by piston blow-by. Since process changes are still being implemented to handle the more difficult feedstocks, accurate figures on future equipment requirements cannot be made at this time. At the present, however, the recovery and reuse of used motor oils appears to be marginally profitable. Process optimization to increase the yield of products with a higher resale value could improve the economics.

Mining Wastes

Every year mining and related operations cause some 500 billion gallons of mine drainage containing millions of tons of acid and acid salts to degrade over 10 thousand miles of surface streams and 15 thousand acres of impounded water in the Appalachian region of the United States.

Several interesting procedures for abating acid mine pollution have been developed in the last two or three years. The first involves the use of a permeable plug to neutralize and seal acid mine drainage sources in one operation. Pulverized limestone is pneumatically placed in the mine portal to provide a contact time of appoximately 25 minutes to effect neutralization of seepage (Figure 24). Iron hydroxide (and possibly calcium sulfate) precipitated during this neutralization gradually fills the pores of the plug and seals the mine opening Field tests of this technique have indicated a reduction in flow from 7 GPM to 0.5 GMP in 55 days and the pH of the acid mine water was raised from 3.1 to 5.8. A finished seal in an actual mine with a 4-1/3' by 12' drift having 25 feet of roof contact and 36 feet of length on the base was placed at the rate of 850 pounds per minute at a cost of $3,048. The flow of 3 GPM has been essentially stopped and the plug is currently withstanding a hydrostatic head of 6.3 ft. Analyses indicate that the pH of the acid mine water increased from 3.0 to 6.9 with a simultaneous change from 300 MG/L of acidity to 160 MG/L of alkalinity.

A potential breakthrough in mine drainage technology has recently been developed. The process, "Neutrolosis," utilizes neutralization and reverse osmosis in combination. Mine drainage is pre-filtered and then passed through a multi-stage reverse osmosis unit The concentrated brine is neutralized with lime and clarified. The clarified effluent can be recycled and blended with the feed to the R.O. unit. This process recovers 98% of the drainage water, produces a sludge suitable for disposal by simple landfill and completely eliminates the brine disposal problem. Over-all rejection efficiencies of 97-98% have been obtained for calcium, magnesium, sulfate, iron and aluminum along with 79% reduction in conductance and 82% reduction in acidity. Average water recovery for the R.O. unit was 91% at a water flux of just over 11 Gal/FT^2/Day. A flux decline of less than 2 Gal/FT^2/Day was noted in 100 hours of operation but the membrane fouling was not irreversible and could be controlled by rapid pressure changes and a flush cycle. Larger-scale, long-term evaluations are currently being made to determine membrane life and obtain accurate cost information (Figure 25).

In addition to transferring technology we must all be on the look-out for technology from other disciplines which can be adopted for environmental protection. Our mine pollution control research program has, for example, looked to space technology for a possible answer. One very desirable way of attacking the acid mine drainage problem is to prevent the formation of the acid drainage in the first place. We are currently evaluating the concept of mining coal in an oxygen-free atmosphere. Miners are equipped with modified "space suits" complete with their own life support systems including an emergency rebreather, radio transmitter/receiver and an umbilical hose which is connected to either a portable rebreather or a fixed rebreather-ciller module. The suit has three layers, an undergarment to absorb body moisture, a gas-tight middle garment and a heavy-duty outer work garment. The mine, equipped with a gas lock curtain at the mine portal, is filled with inert gas, e.g., nitrogen or methane. Modification of existing conventional mining equipment will be minimal for such an operation The completed feasibility study indicates that the cost of equipping a 5,000-ton-per-day underground coal mine with inert gas blanketing would not increase the installed cost of the mine by more than 12%. In a non-gassy mine, the operating costs of inert gas operation may increase the operating costs of the mine by a few percent but in the case of a gassy coal mine, operation in an inert gas atmosphere may actually decrease the cost of the mine operation by as much as 20% when credit is applied for the methane gas that is collected and sold. While this mining concept must still be regarded as in an exploratory stage, it holds substantial promise for ultimate practicability, especially considering the advantages in health (elimination of black lung disease) and safety (elimination of explosion hazard) which the approach may offer.

Conclusion

A variety of newly-developed, cost-effective treatment and control techniques are available to abate pollution from many major sources. Many of these techniques have already been demonstrated at full scale and are ready for wide-scale application. Many new techniques, which incorporate the very desirable aspects of by-product recovery and reuse, are also available which can stimulate new industrial activities and change the economics of various product lines. Pollution control activities, in some instances, are even profit-making and resource conservation opportunities in addition to being an increasingly necessary part of man's responsibility to himself and his children to preserve the environment.

Man has the ability to control pollution and future prospects for achieving a clean environment through technology transfer and imagineering are bright. Hopefully, history will record that in the same decade that man first reached and explored the moon he also realized the finite nature of the earth and its environment; that he "returned" to protect it and that he succeeded!

REFERENCE MATERIAL

The following Research, Development, and Demonstration Grant, Contract, and in-house project reports which relate to the subjects discussed are available from The National Technical Information Service, Department of Commerce, Springfield, Virginia 22151, (paper copies - $3.00 and $6.00, microfiche copies - $0.95) or at the Government Printing Office, Washington, D.C. 20402, at the designated sale price. Further inquiries concerning these reports should be directed to the Project Reports System, Office of Research and Development, Water Quality Office, Environmental Protection Agency, Washington, D.C. 20242.

Report Number	Title/Author	Source
10000---04/70	Research, Development and Demonstration Projects--Division of Applied Science and Technology; by FWQA, Washington, D.C.	PB 192 091
11000---01/70	Storm and Combined Sewer Demonstration Projects--January 1970; by Storm and Combined Sewer Branch, Division of Applied Science and Technology, FWQA, Washington, D.C.	PB 190 799
11020EK010/69	Combined Sewer Separation Using Pressure Sewers; by American Society of Civil Engineers, Cambridge, Mass.	PB 188 511
11023EV006/70	Microstraining and Disinfection of Combined Sewer Overflows; by Cochrane Div., Crane Co., King of Prussia, Pa.	GPO--70¢
11024---06/70	Combined Sewer Overflow Abatement Technology; Storm and Combined Sewer Pollution Control Branch, Division of Applied Science and Technology, FWQA, Washington, D.C.	GPO--$2.50
12000---01/70	Projects of the Industrial Pollution Control Branch; by Industrial Pollution Control Branch, Division of Applied Science and Technology, FWQA, Washington, D.C.	PB 189 766
12000---07/70	Projects of the Industrial Pollution Control Branch, July 1970; by Industrial Pollution Control Branch, Division of Applied Science and Technology, FWQA, Washington, D.C.	GPO--$1.75

Report Number	Title/Author	Source
12060---10/69	Current Practice in Potato Processing Waste Treatment; by University of Washington, Seattle, Washington.	GPO--$1.00
12060---04/70	Proceedings First National Symposium on Food Processing Wastes; by FWQA, USDA, National Canners Assoc., and Northwest Food Processors Assoc.	(at press)
12060FAD10/69	Aerobic Treatment of Fruit Processing Wastes; by Snokist Growers, Yakima, Washington.	PB 188 506
13030ELY12/69	Collected Papers Regarding Nitrates in Agricultural Waste Waters; by FWQA, San Francisco, California, U.S. Bureau of Reclamation, and California Department of Water Res.	GPO--$1.50
14010DM003/70	New Mine Sealing Techniques for Water Pollution Abatement; by Halliburton Company, Duncan, Okla.	GPO--$1.50
14010DYK03/70	Treatment of Acid Mine Drainage by Reverse Osmosis; by Rex Chainbelt, Inc., for the Commonwealth of Pennsylvania	GPO--55¢
14010DZM08/70	Feasibility Study of Mining Coal in an Oxygen Free Atmosphere; by Island Creek Coal Co., Holden, W.V. and Cyrus Wm. Rice Div., NUS Corp., Pittsburgh, Pa.	GPO--$1.50
14010EIZ01/70	Limestone Treatment of Acid Mine Drainage; by Bituminous Coal Research, Inc., Monroeville, Pa.	GPO--$1.25
15080EOS10/70-1	Evaluation of Selected Earthmoving Equipment for the Restoration of Oil Contaminated Beaches; by URS Research Co., San Mateo, Calif.	GPO--$1.50
17010---01/70	Treatment Techniques for Removing Phosphorus from Municipal Wastewaters; by J.J. Convery, Advanced Waste Treatment Research Laboratory, FWQA, Cincinnati, Ohio.	(at press)
17010DHT09/70	Methanol Requirement and Temperaturre Effects in Wastewater Denitrification; by Gulf South Research Institute, New Iberia, La.	(at press)

Report Number	Title/Author	Source
17010DRD07/70	A Study of Nitrification & Denitrification; by Aerojet General Corp., El Monte, Calif.	GPO--$1.00
17010ED006/70	Phosphorus Removal Using Chemical Coagulation and a Continuous Countercurrent Filtration Process; by Johns-Manville Products Corp., Manville, N.J.	GPO--65¢
17020---12/68	A Comparison of Expanded-Bed and Packed-Bed Adsorption Systems; by FMC Corporation.	PB 187 756
17020DVJ05/69	Appraisal of Granular Carbon Contacting: Phase I & II Phase III by Swindell-Dressler Co., Pittsburgh, Pa.	 PB 190 168 PB 190 167
17050DAL05/70	Granular Carbon Treatment of Raw Sewage; by FMC Corporation.	GPO--$1.00
17050DNW05/70	Investigation of the Use of High-Purity Oxygen Aeration in the Conventional Activated Sludge Process; by Union Carbide Corporation, Linde Division, Tonawanda, N.Y.	PB 194 241
17090---06/69	Cost and Performance Estimates for Tertiary Wastewater Treating Processes; by Robert A. Taft Water Research Center, Cincinnati, Ohio.	PB 189 953

TABLE I

COMPARISON OF ALUM DOSED AND ALUMINATE DOSED ACTIVATED SLUDGE UNITS

CONSTITUENT	RAW SEWAGE mg/l	FINAL EFF - ALUMINATE DOSED UNIT mg/l	FINAL EFF - ALUMINATE DOSED UNIT % REMOVAL	FINAL EFF ALUM DOSED UNIT mg/l	FINAL EFF ALUM DOSED UNIT % REMOVAL
COD	310	23	93	35	89
TOTAL PHOS.	11.6	1.2	90	2.0	83
NITROGEN (ALL FORMS)	23.0	9.4	59	10.7	53
SUSPENDED SOLIDS	157	7	96	21	87
TURBIDITY PRI EFF (JTU)	46	3.1	93	7.4	85
ALKALINITY (as $CaCO_3$)	182	165		67	
pH	7.2	7.6		6.9	

TABLE II

SUMMARY OF PERFORMANCE OF THE MOVING BED FILTER

Treatment of Raw Sewage

(AFTER JOHNS-MANVILLE)

PARAMETER	AVERAGE VALUES, mg/l RAW SEWAGE	AVERAGE VALUES, mg/l MBF EFFLUENT	% REMOVAL
TOTAL PHOSPHORUS	21.5	2.16	90
TSS	156	27	83
TURBIDITY (JTU)	119	16	87
BOD	115	19	84

NOTE: COADULATED WITH 200 mg/l ALUM AND APPROX. 0.5 mg/l MAGNIFLOC 860A

TABLE III

Full-Scale Plants Utilizing Chemical Treatment

Treatment in Primary	Flow MGD	Chemical	Status
Detroit, Michigan	600	Iron	Design
Rochester, New York	100	Lime	Const.
Bay City, Michigan	12	Iron	Const.
Cleveland, Ohio	10	Iron	Design
Painesville, Ohio	5	Iron	Design
Hatfield Township, Pa.	5	Lime	Design
Holland, Michigan	4	Lime	Const.
Wyoming, Michigan	4	Iron	Design
Mentor, Ohio	2	Iron	On-Stream
Mineral Addition to Aerator			
Chicago, Illinois	30	Iron	Design
Seattle, Washington	20	Iron & Alum.	Design
Pomona, California*	2	Alum. & Sod.Al.	Completed
Xenia, Ohio*	1	Alum.	Completed
Manassas, Virginia*	1	Alum. & Sod.Al.	Completed
Texas City, Texas*	1	Iron & Alum.	Completed
Tertiary Treatment			
South Lake Tahoe, Calif.	7.5	Lime	On-Stream
Manville, New Jersey	5	Alum.	On-Stream
Piscataway, Maryland	5	Lime	Const.
Colorado Springs, Colo.	2	Lime	Const.
Santee, California	2	Iron & Alum.	On-Stream

*R&D Studies

TABLE IV

Total Treatment P-C Plants

Plant	Organic Removal %	Effluent Concentration
Blue Plains	95-98	TOC=6
Lebanon	95	TOC=11
Ewing Lawrence	95-98	TOC=3-5
New Rochelle	95	COD=8

TABLE V

Full-Scale Independent Physical-Chemical Plants

Location	Flow	Status
Niagara Falls, New York	60	Planned
Cleveland Ohio	40	Design
Garland, Texas	30	Design
Fitchburg, Massachusetts	15	Design
Rocky River, Ohio	10	Bids Taken
Cortland, New York	10	Planned
Clay, New York	10	Planned
Owosso, Michigan	6	Design
Painesville, Ohio	5	Design
Waterford, New York	2	Planned

TABLE VI

Aeration Detention Times for Equivalent Treatment

Detention Time Air Systems Hrs.	% BOD Removal	Detention Time Oxygen System-Hrs.
3.0	84	1.00
4.0	87	1.33
5.0	90	1.66
6.0	92	2.00

TABLE VII

Full-Scale Plants Designed for Oxygen Aeration

Location	Flow, MGD	Status
Detroit, Michigan	300	Bids Solicited
New York, New York	20	On Stream, Fall 71
Winnipeg, Canada	15	Design
New Rochelle, New York	15	Plans Approved
Speedway, Indiana	12	Design
York, Pennsylvania	8	Design

TABLE VIII

CHANGE IN COMPOSITION OF PROCESS STREAM DURING TREATMENT

PROCESS STREAM	mg/l							
	COD	S.S.	TOTAL P	ORG. N	NH$_3$ N	NO$_2$ N	NO$_3$ N	TOTAL N
RAW WASTEWATER	320	157	12.6	10.3 +	11.3 +	/	/ =	21.6
PRIMARY EFFLUENT	218	90	11.9	5.9 +	13.7 +	/	/ =	19.6
HIGH-RATE EFFLUENT	64	9	2.8	0.8 +	7.7 +	1.1 +	4.3 =	13.9
NITRIFIED EFFLUENT	43	7	2.6	0.4 +	0.6 +	0.3 +	11.5 =	12.8
FINAL (DENITRIFIED) EFFLUENT	44	7	1.5	0.4 +	0.3 +	0.3 +	0.9 =	1.9
PERCENT (%) REMOVAL	86	95	88					91

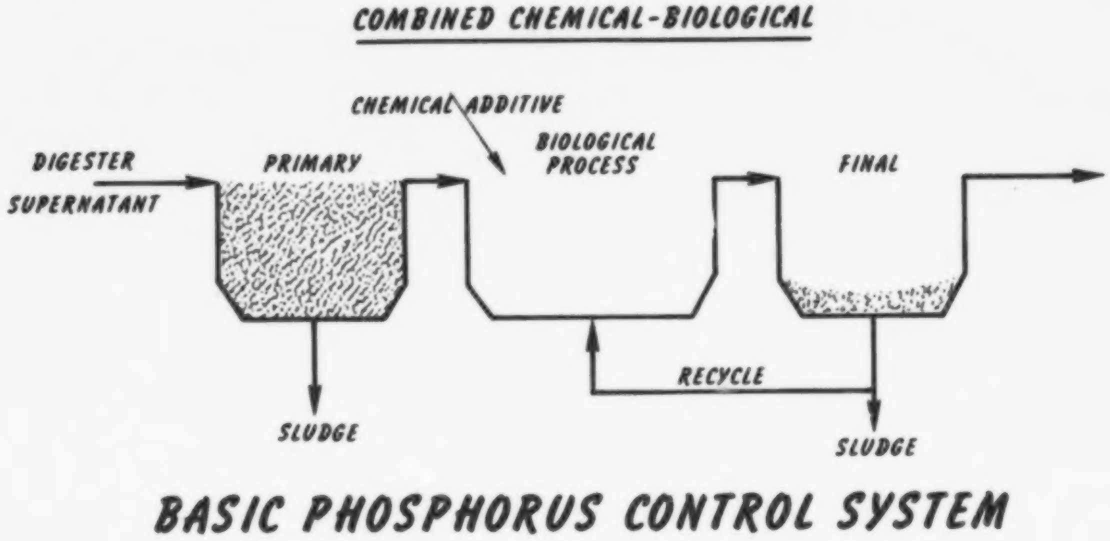

COMBINED CHEMICAL-BIOLOGICAL
CHEMICAL ADDITIVE
DIGESTER
SUPERNATANT
PRIMARY
BIOLOGICAL PROCESS
FINAL
RECYCLE
SLUDGE
SLUDGE
BASIC PHOSPHORUS CONTROL SYSTEM

Figure 1: Phosphorus Removal by Chemical Addition to Biological Process

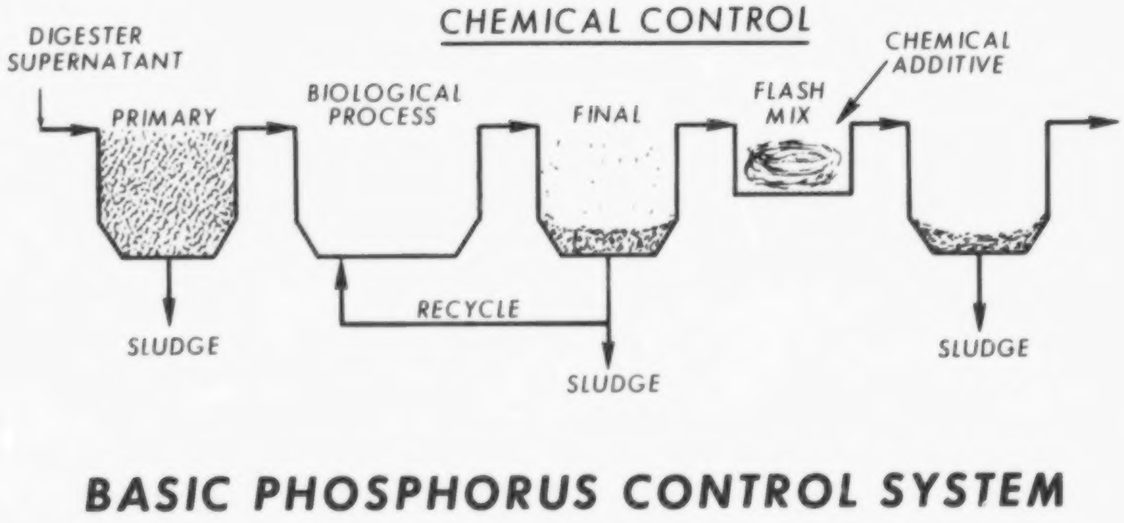
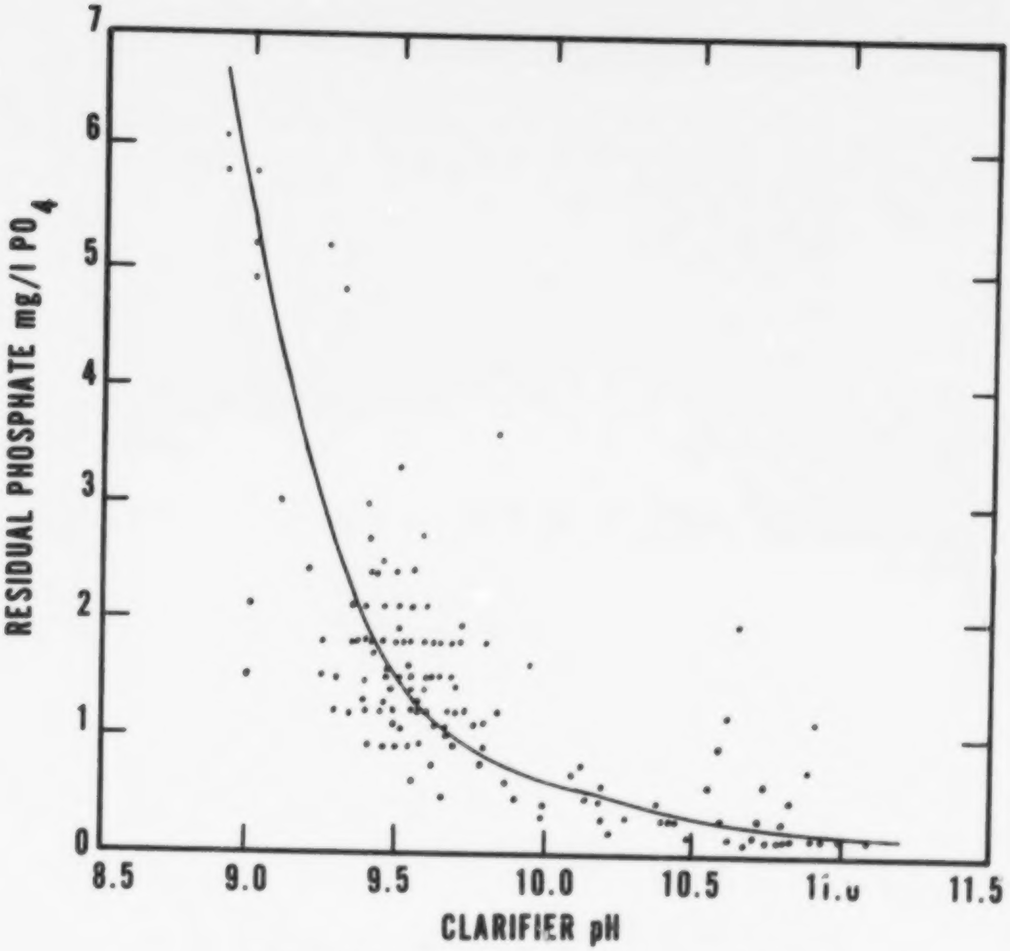

CHEMICAL CONTROL
DIGESTER
SUPERNATANT
PRIMARY
BIOLOGICAL PROCESS
FINAL
FLASH MIX
CHEMICAL ADDITIVE
RECYCLE
SLUDGE
SLUDGE
SLUDGE
BASIC PHOSPHORUS CONTROL SYSTEM

Figure 2: Phosphorus Removal by Chemical Addition to Tertiary Coagulation-Sedimentation Step



EFFECT OF pH ON RESIDUAL PHOSPHATE
AFTER LIME CLARIFICATION AND FILTRATION

Figure 3

BASIC CONCEPT OF MOVING BED FILTER

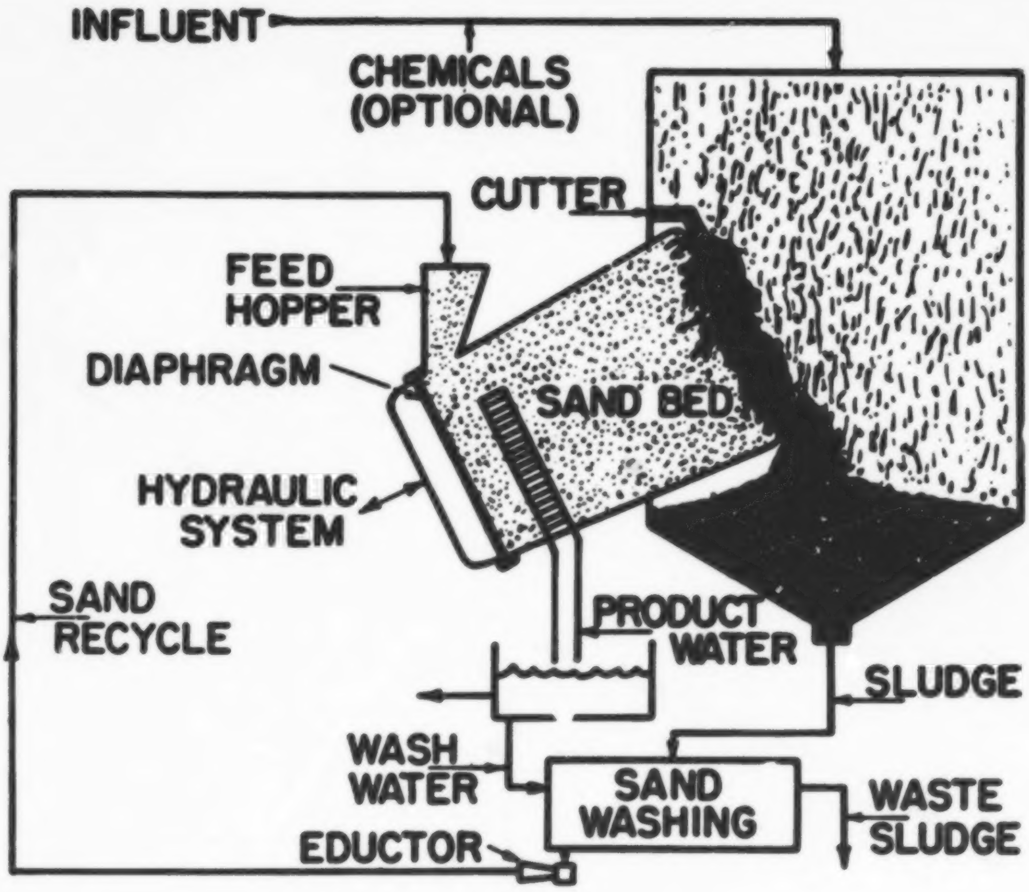
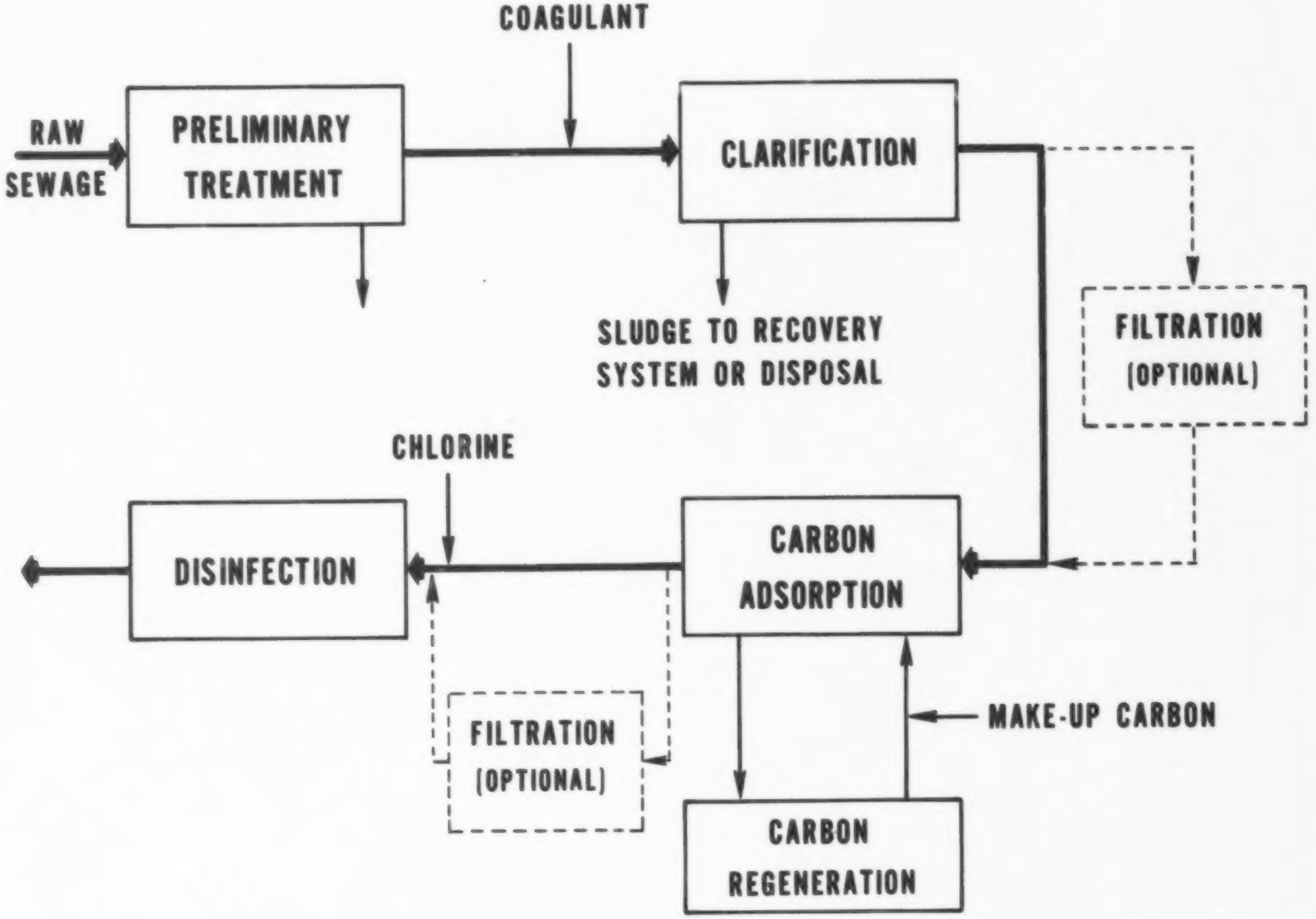

INFLUENT
CHEMICALS (OPTIONAL)
CUTTER
FEED HOPPER
DIAPHRAGM
SAND BED
HYDRAULIC SYSTEM
SAND RECYCLE
PRODUCT WATER
SLUDGE
WASH WATER
SAND WASHING
WASTE SLUDGE
EDUCTOR

Figure 4


COAGULANT
RAW SEWAGE
PRELIMINARY TREATMENT
CLARIFICATION
SLUDGE TO RECOVERY SYSTEM OR DISPOSAL
FILTRATION (OPTIONAL)
CHLORINE
DISINFECTION
CARBON ADSORPTION
FILTRATION (OPTIONAL)
MAKE-UP CARBON
CARBON REGENERATION

FLOW DIAGRAM OF A PHYSICAL-CHEMICAL TREATMENT SYSTEM

Figure 5

REMOVAL EFFICIENCIES
PHYSICAL CHEMICAL TREATMENT
BLUE PLAINS PILOT PLANT

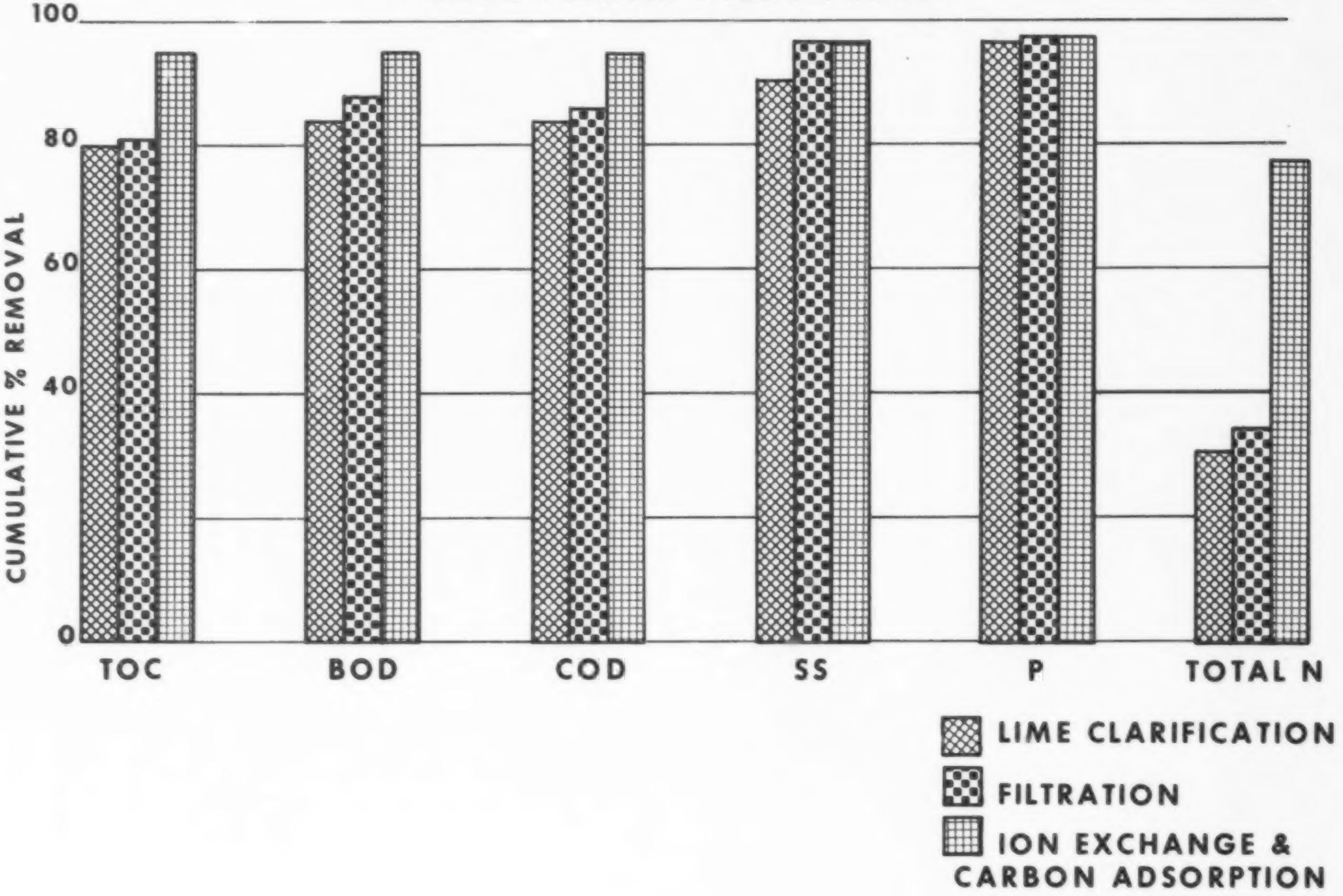


Figure 6

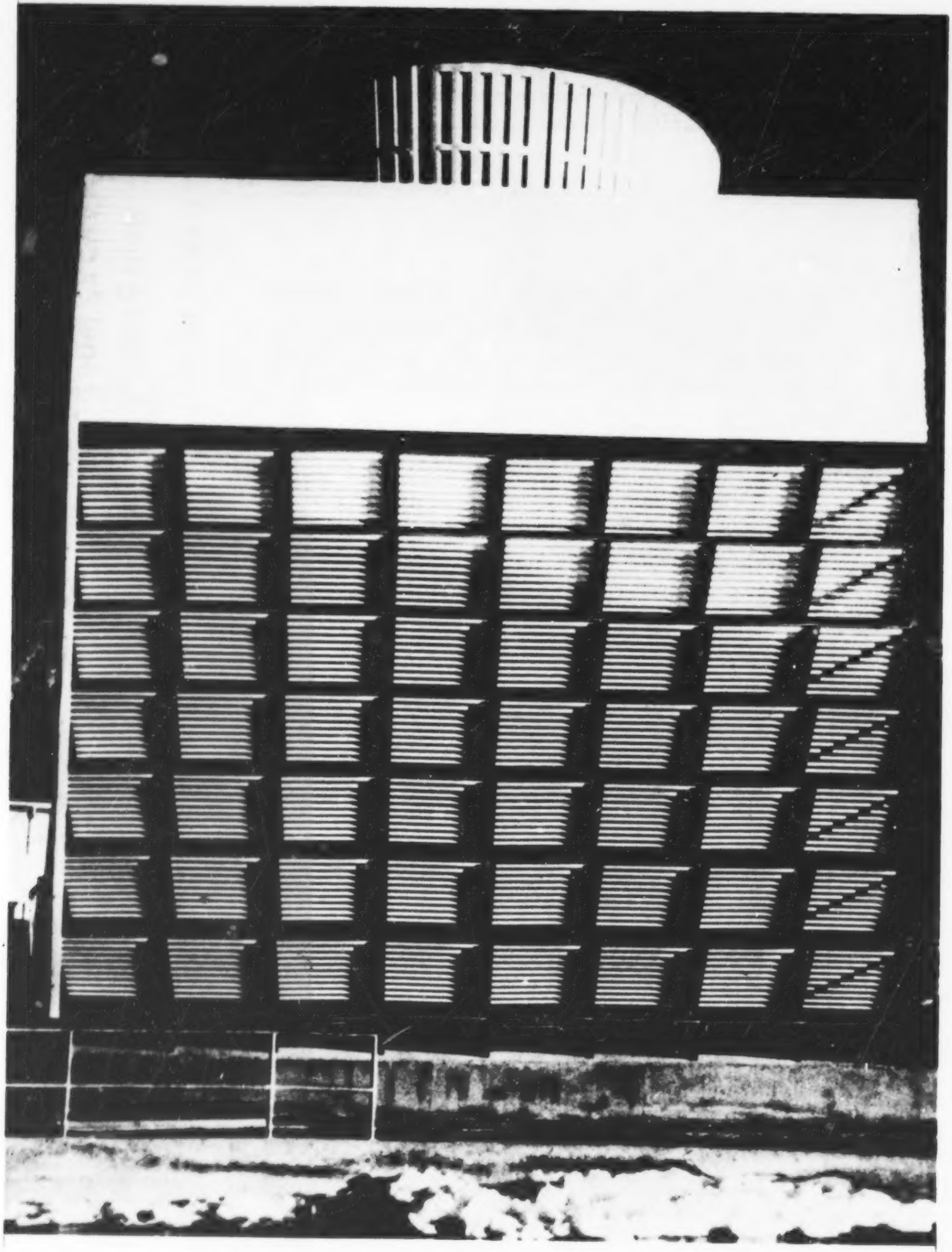


Figure 7: Ammonia Stripping Tower at South Lake Tahoe, California

SCHEMATIC DIAGRAM OF MULTI-STAGE OXYGENATION SYSTEM

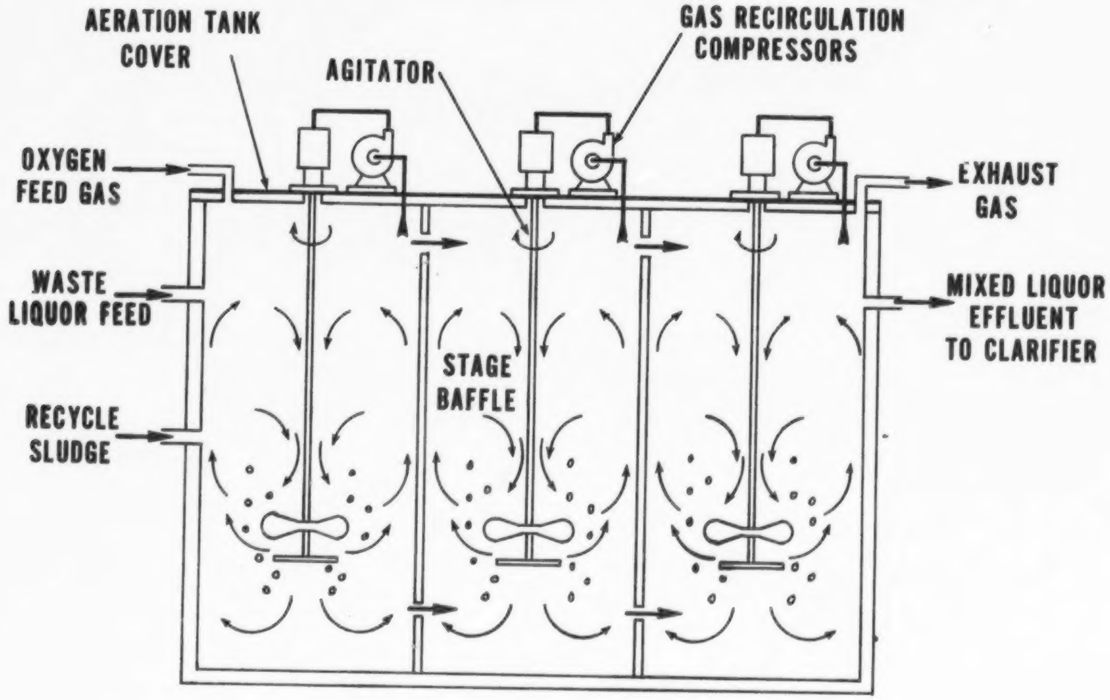
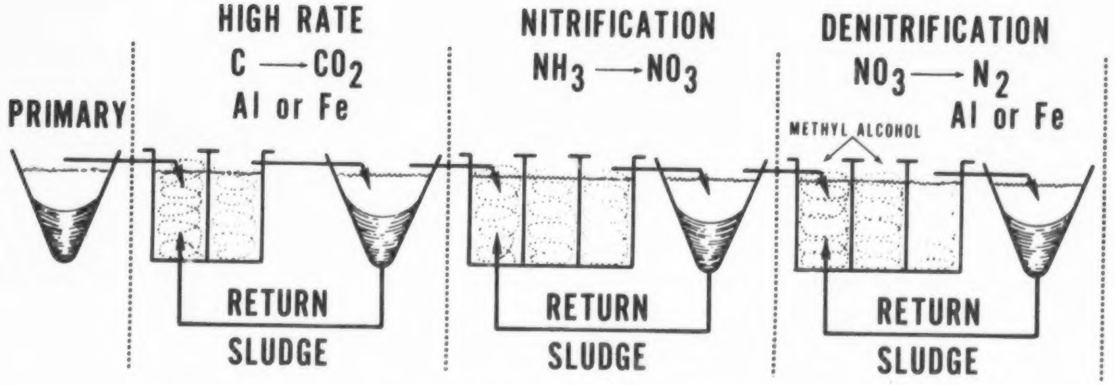

AERATION TANK COVER
GAS RECIRCULATION COMPRESSORS
AGITATOR
OXYGEN FEED GAS
EXHAUST GAS
WASTE LIQUOR FEED
MIXED LIQUOR EFFLUENT TO CLARIFIER
STAGE BAFFLE
RECYCLE SLUDGE

Figure 8


HIGH RATE
C → CO_2
Al or Fe
NITRIFICATION
NH_3 → NO_3
DENITRIFICATION
NO_3 → N_2
Al or Fe
PRIMARY
METHYL ALCOHOL
RETURN SLUDGE
RETURN SLUDGE
RETURN SLUDGE

THREE SLUDGE SYSTEM FOR NITROGEN REMOVAL
SCHEMATIC OF THREE SLUDGES SYSTEMS FOR NITROGEN REMOVAL

Figure 9

MODIFICATIONS OF THE DENITRIFICATION PROCESS

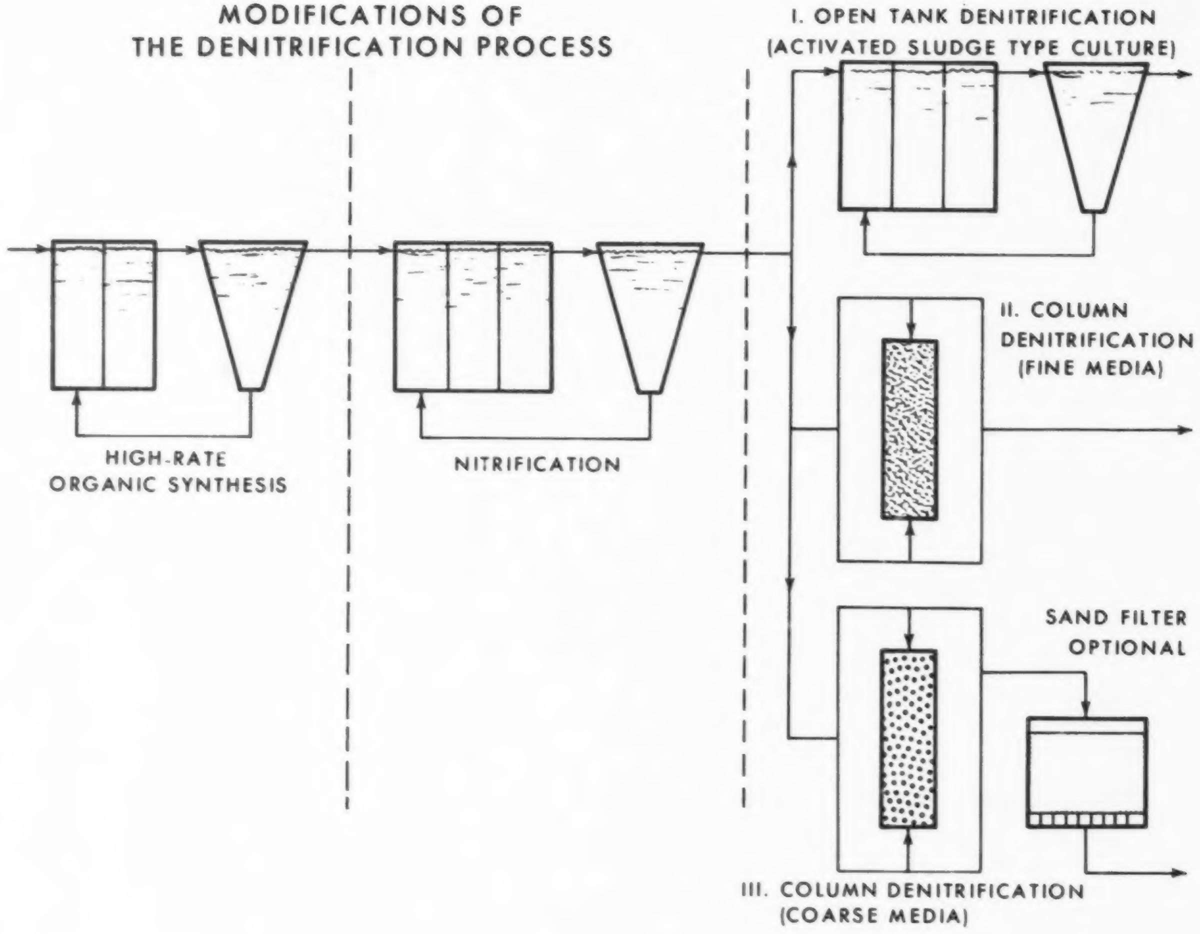

I. OPEN TANK DENITRIFICATION
(ACTIVATED SLUDGE TYPE CULTURE)
II. COLUMN DENITRIFICATION (FINE MEDIA)
SAND FILTER OPTIONAL
III. COLUMN DENITRIFICATION (COARSE MEDIA)
HIGH-RATE ORGANIC SYNTHESIS
NITRIFICATION

Figure 10

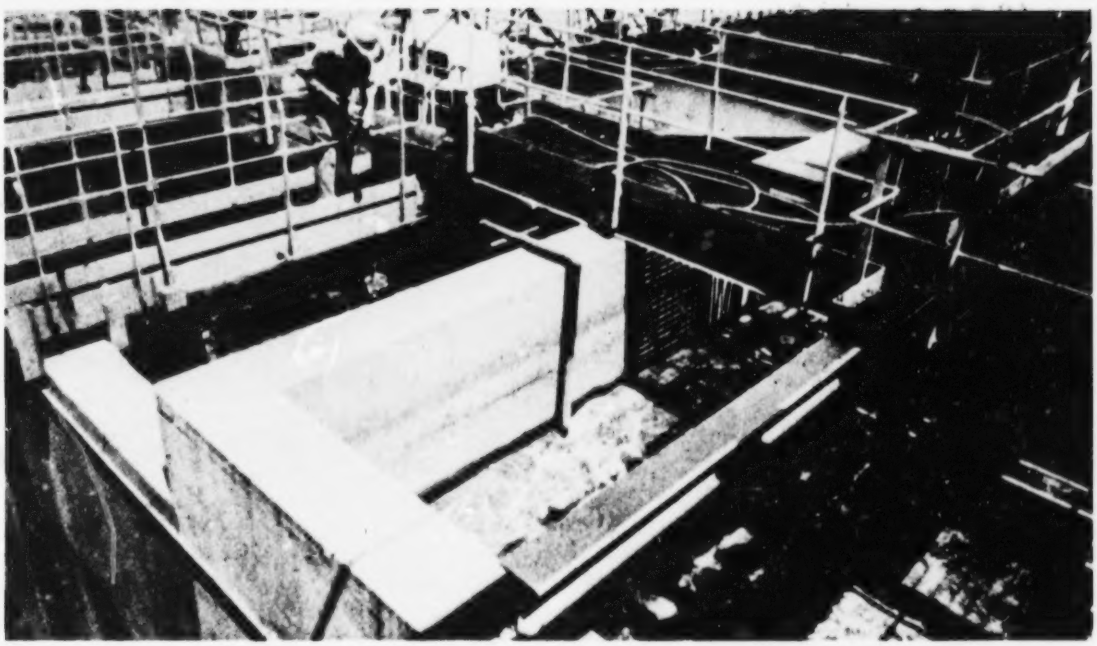


Figure 11: Treatment of Acid Rinse Waters from HCl Pickling Process

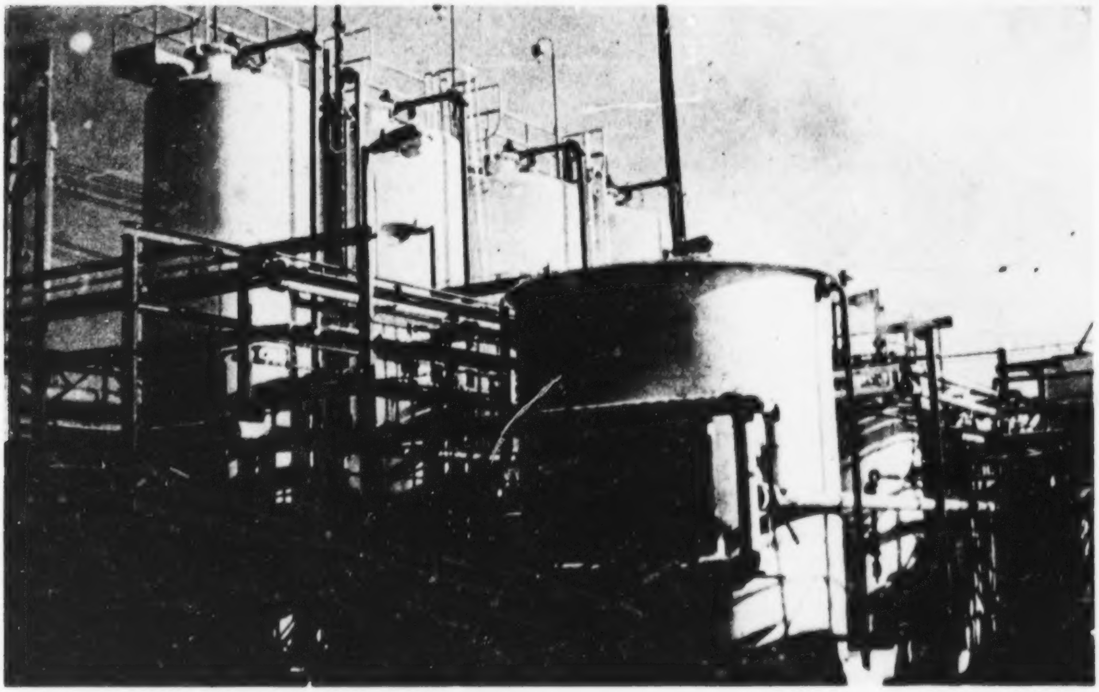


Figure 12: Closed-Loop System for Treating and Recovering Phenolic Wastes

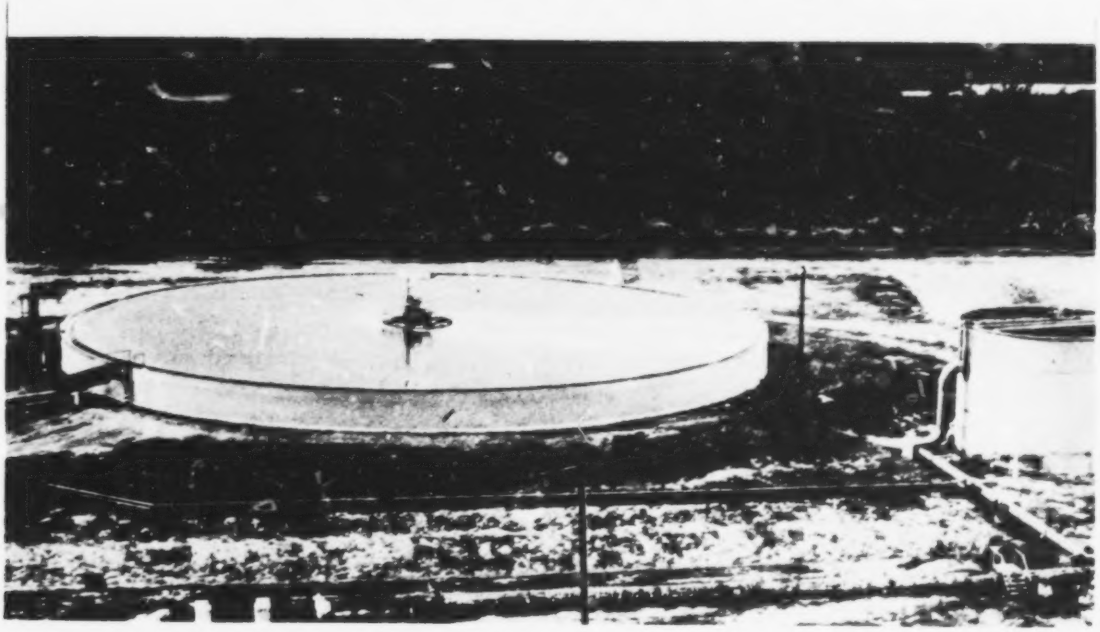


Figure 13: Color Removal by Lime Clarification at Kraft Paper Plant

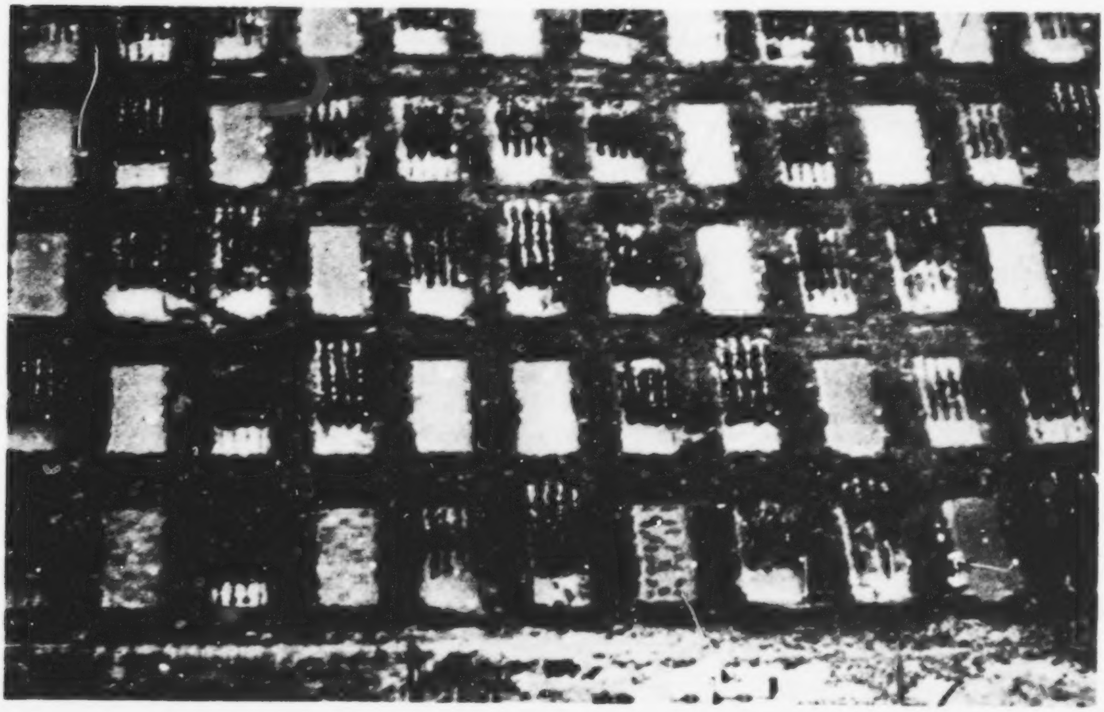


Figure 14: Agricultural Test Plots Using Processed Sludge from Pulp and Paper Plant as Soil Conditioner

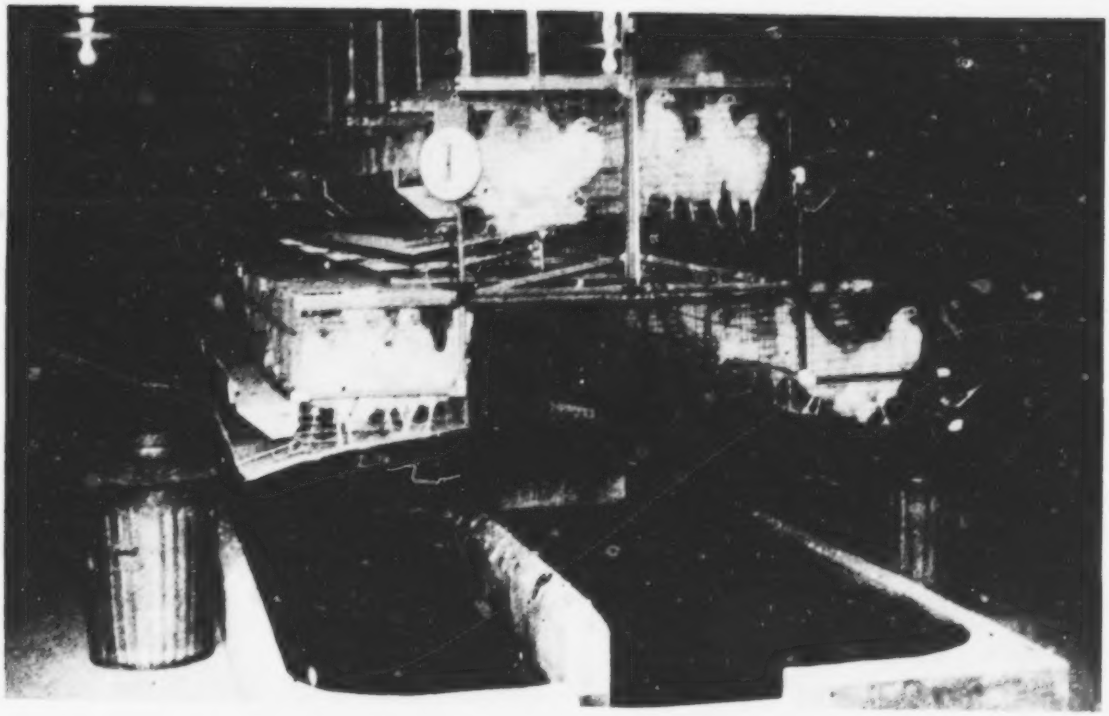


Figure 15: Caged Hens Suspended Directly Over Oxidation Ditch

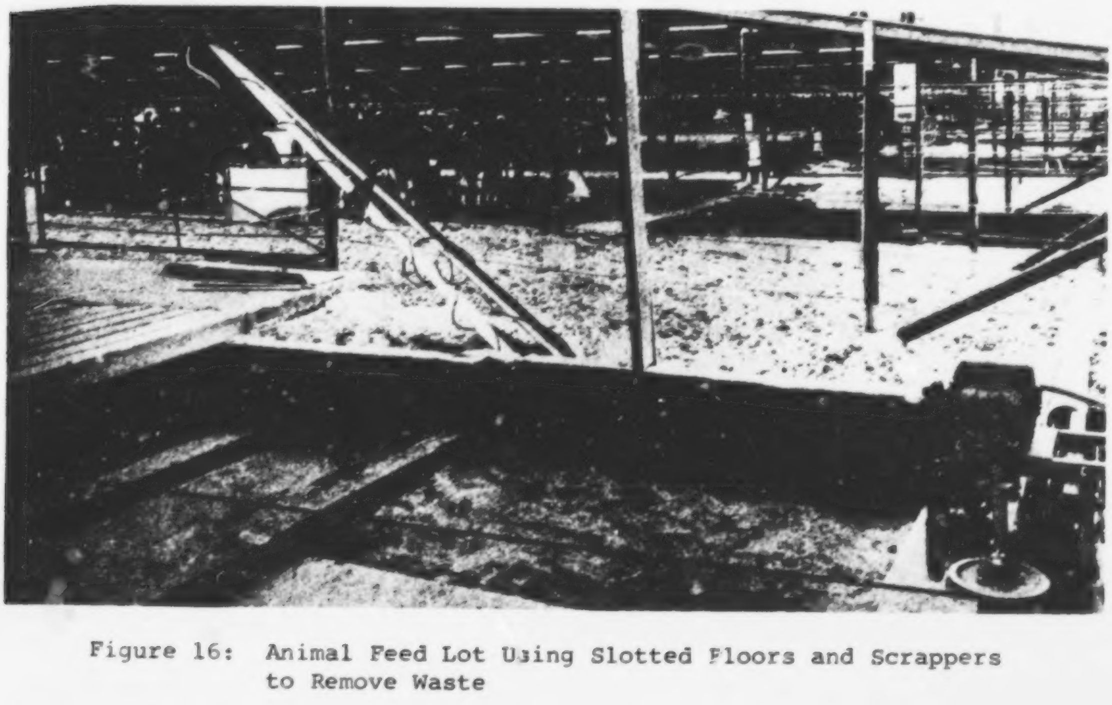


Figure 16: Animal Feed Lot Using Slotted Floors and Scrappers to Remove Waste

Figure 17: Spray Irrigation for Disposal of Bilogically-Treated Feed Lot Wastes

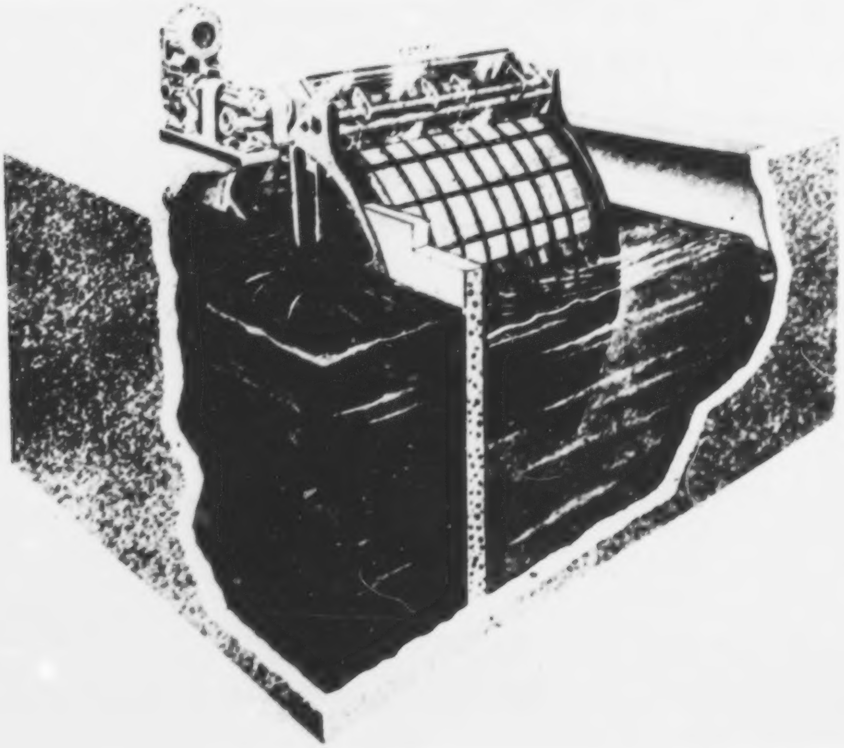


Figure 18: Microstrainer Used for Treatment of Combined Sewer Overflows

Figure 19: Control Center for Automated Sewer Flow Control Operation to Maximize Storage Capacity of Existing Sewer System

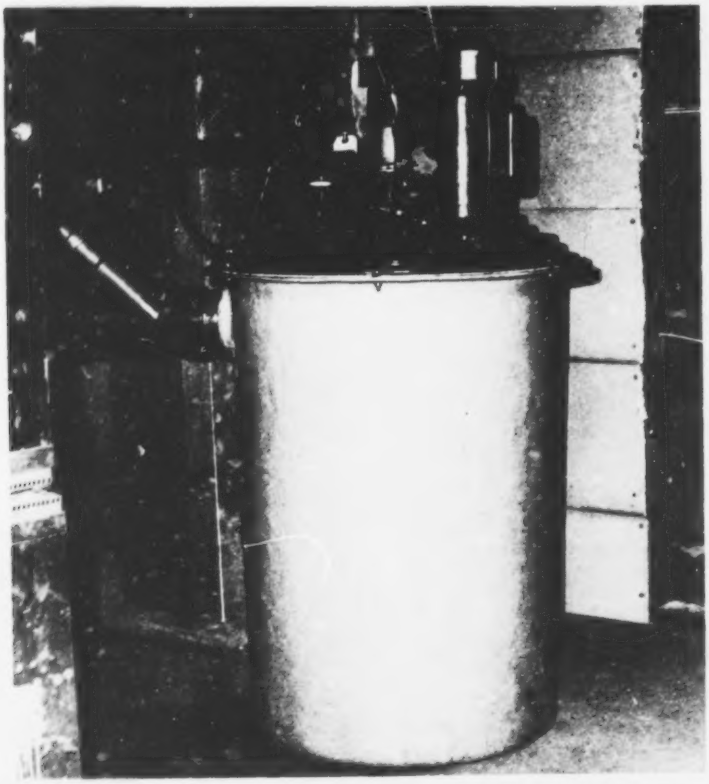


Figure 20: Individual Household Grinder-Pump Used in Conjunction with Small Diameter Pressurized Sewer System

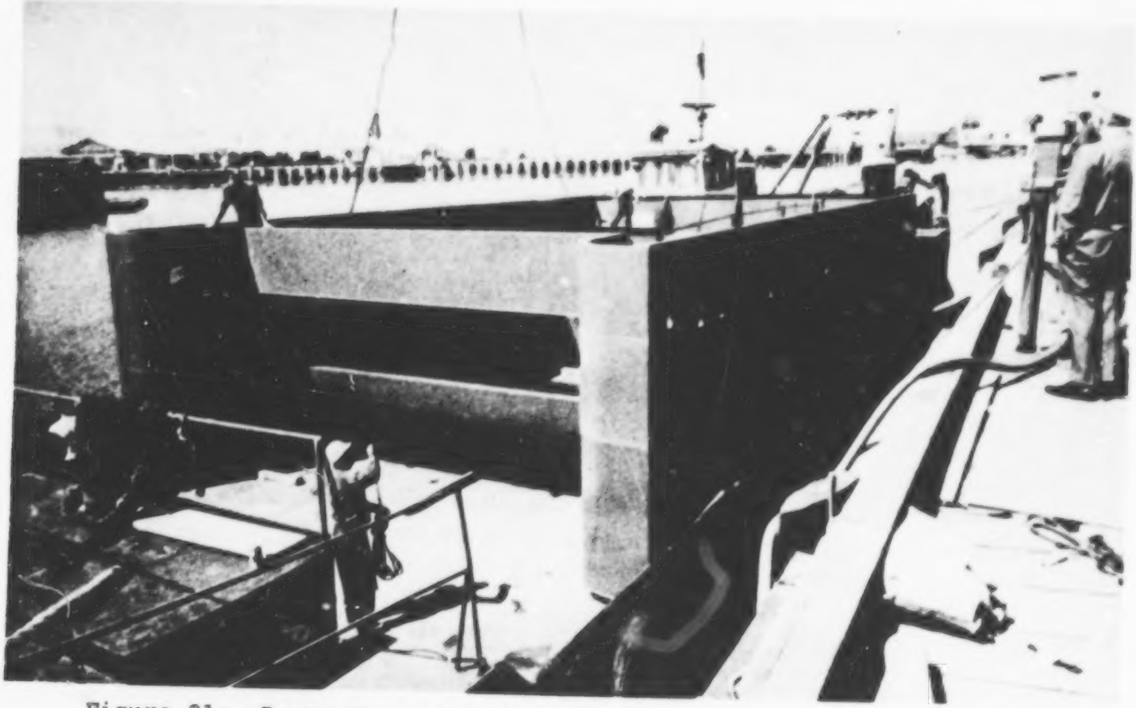


Figure 21: Barge Mounted Skimmer for Collection and Separation of Oil-Water Mixtures

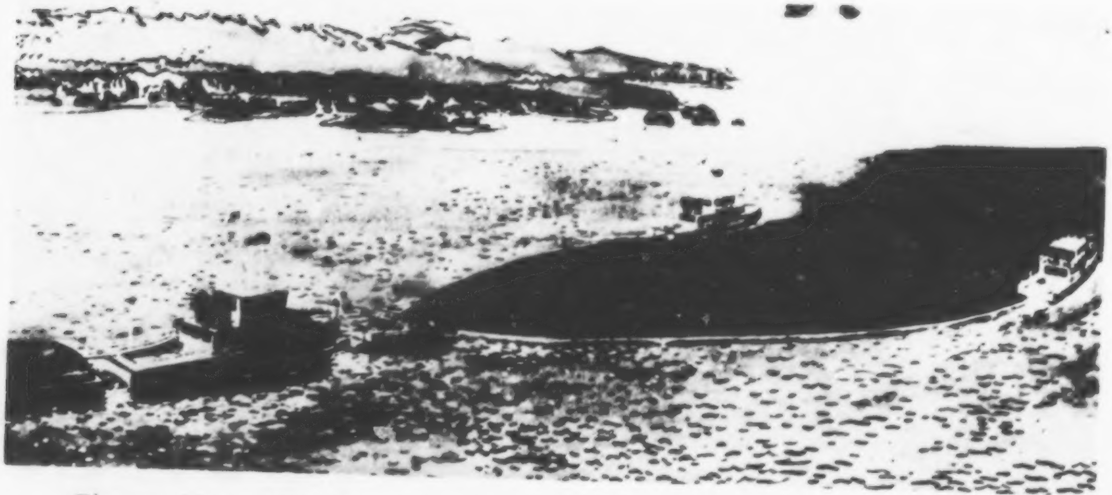


Figure 22: Pictorial View of Complete Oil Spill Recovery System

Figure 23: Motor Grader in Use Cleaning Up Oil-Contaminated Beach

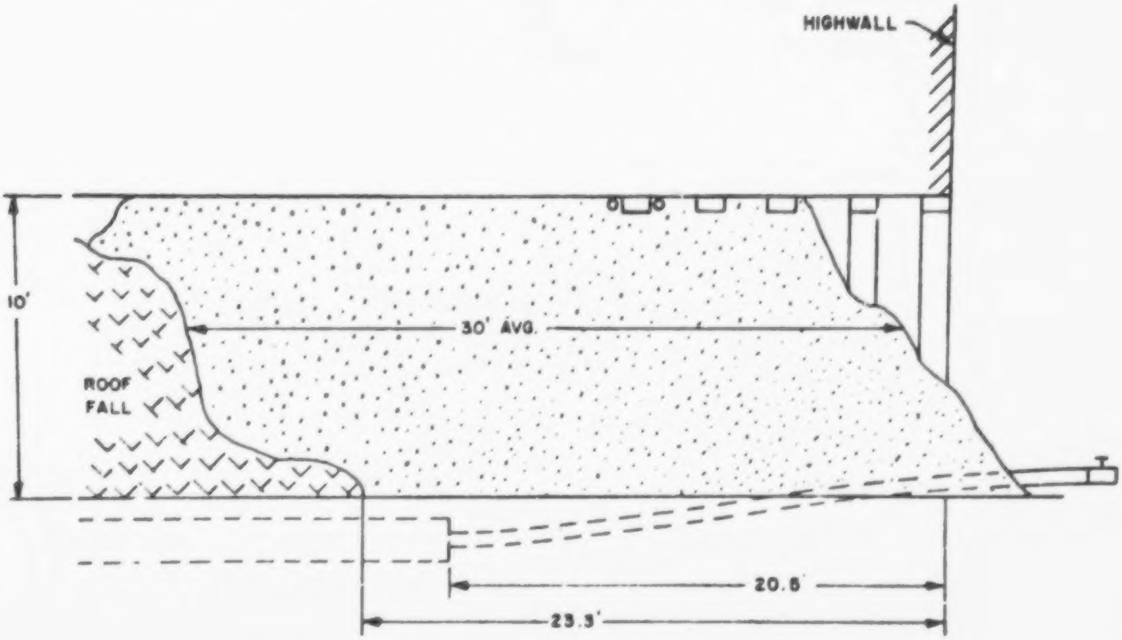

HIGHWALL
10'
30' AVG.
ROOF FALL
20.8'
23.3'

Figure 24: Pulverized Limestone Mine Seal

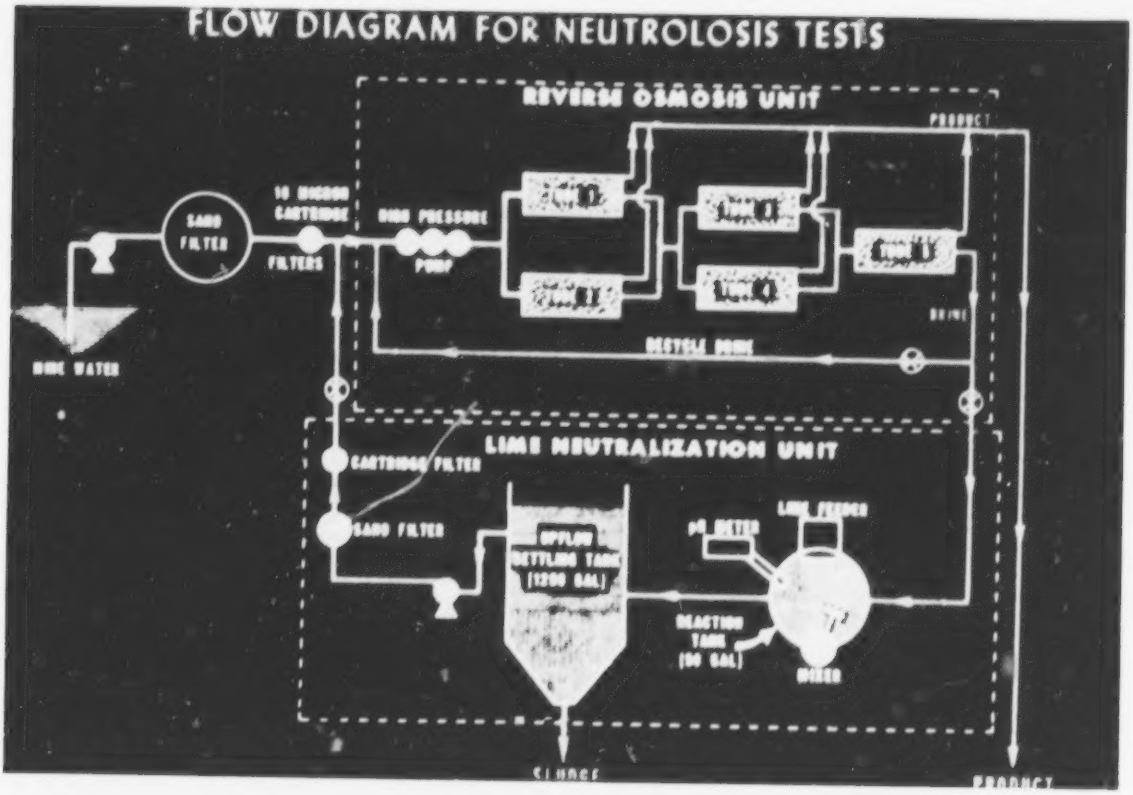

FLOW DIAGRAM FOR NEUTROLOSIS TESTS
REVERSE OSMOSIS UNIT
PRODUCT
SAND FILTER
10 MICRON CARTRIDGE FILTERS
HIGH PRESSURE PUMP
BRINE
RECYCLE BRINE
MINE WATER
LIME NEUTRALIZATION UNIT
CARTRIDGE FILTER
SAND FILTER
UPFLOW SETTLING TANK (1200 GAL)
pH METER
LIME FEEDER
REACTION TANK (50 GAL)
MIXER
SLUDGE
PRODUCT

Figure 25: Flow Diagram for Neutrolosis Tests

INCORPORATION OF NEW POLLUTION CONTROL TECHNOLOGY IN PROCESS DESIGN AND CONTROL

By Roy F. Weston, President
Roy F. Weston, Inc., West Chester, Pennsylvania, USA

Environmental protection pressures on the private sector and the research and demonstration programs of the Federal Environmental Protection Agency have greatly stimulated the development of new technology for solving water pollution control problems in the United States. The preceding paper from the Environmental Protection Agency indicates the scope and depth of that agency's programs.

The objective of new technological development is to improve performance and/or reduce costs. This paper summarizes factors that should be considered in introducing new pollution control technology in process design and control and gives illustrations of the approach taken to incorporate new technology.

It must be recognized that the word "new" is a relative term. Newness is a function of time and use. That which is "new" to me may be "old" to you. That which is new to the field of water pollution control may be old and well established in some other field of technology. Nothing is completely new because new technology evolves; it is seldom revolutionary. Nevertheless, most of us are cautious about, if not fearful of, that which is new to us. We believe that there is risk involved in using something new. Therefore, we can justify something new only if the expected benefits exceed the anticipated direct costs. The use of something new to replace something proven or established may be justified only if:

1. Equivalent results are obtained at lower cost;
2. Better results are obtained at the same cost; or
3. Heretofore unattainable results are obtained at reasonably higher costs (1).

Ordinarily the above criteria should and do control decisions. However, now and then someone is intrigued by a new device or is desirous of the prestige associated with being among the first to use a glamorous process or systems. Under these conditions, the customary rules are abandoned.

Although the above criteria may be all that is needed to assure the successful incorporation of new technology in water pollution control, it will be desirable, in most cases, to utilize an orderly and detailed approach (i.e., a methodology) for minimizing risk. The purposes of such a methodology are to encourage the use of new technology and increase the chances of success of new technology applications. Obviously, the specific steps to be taken and the thoroughness of the approach will depend on the economic consequences of failure. The use of a new device for improving the operation and reducing the maintenance of a sludge dewatering centrifuge, for example, certainly requires neither the breadth nor the depth of the investigation that is required for the use of a new process for a multi-million dollar wastewater treatment facility. Nevertheless, the basic approach will be similar.

First, the problem to be solved must be completely and precisely defined. Then, the available alternatives must be thoroughly and objectively evaluated. Finally, if new technology is justified, the behavioral characteristics, capabilities, and limitations of the new technology must be established so that the detailed design can allow for anticipated or potential problems.

The specific steps to be taken will depend on the kind of technology under consideration. Basically, pollution control is accomplished by prevention and/or correction. Prevention pertains to control or reduction of pollution at its source. Correction pertains to the handling, treatment, and disposal of pollutants after they have been discharged from their source.

In more familiar terms, pollution control is accomplished by:

1. Preventive measures (at-source control or reduction)
2. On-site treatment and/or disposal
3. Off-site treatment and/or disposal
4. Modifications to the natural environment
5. Combinations of the above.

From the viewpoint of technical sophistication, pollution control systems may be conveniently classified into three levels. These are:

1. Effluent treatment
2. Pollution abatement
3. Environmental protection.

These systems are of increasing technical complexity and scope in the order given. Effluent treatment is concerned solely with the treatment system for municipal and industrial effluents. Pollution abatement is concerned with the entire pollution generation system as well as the effluent treatment system and, therefore, includes all effluent pollution-reduction measures. Environmental protection is concerned with the total environmental system and with all the measures (including pollution abatement) that may be utilized to protect the system.

Most of that technology for water pollution control that may be called "new" pertains to effluent treatment. However, it is believed that a "new" and vital technology is emerging for pollution abatement. Also, technology is developing for solving water pollution problems on a regional or river-basin basis and for providing improved water pollution control administration.

For the sake of convenience, the development of a methodology for evaluating new technology will be discussed in the order of the system complexity, i.e., Effluent Treatment; Pollution Abatement; and Environmental Protection.

Effluent Treatment

New effluent treatment technology may be either process or device (equipment, apparatus, machinery, instrument) oriented. Some of the detailed factors to be considered for incorporating new treatment process technology are as follows:

1. Completely and precisely define the problem:

   - a. Establish the source, quantity, quality, mode of occurrence, and variability of the wastewater.
   - b. Determine the impact of the wastewater on the environment (including variability).
   - c. Define the regulatory requirements (including performance bonds and reliability of control).
   - d. Learn the behavioral characteristics of the wastewater and treatment by-products relative to handling, treatment, and disposal.
   - e. Ascertain the physical, institutional, legal, and other constraints.

2. Acquire a basic understanding of the new technology:

   - a. Establish the process kinetics and equilibria.
   - b. Define the interferences (e.g., physical, chemical, biological).
   - c. Fix the capacity limitations.
   - d. Determine the concurrent reactions (e.g., by-products, scale formation, corrosion).
   - e. Ascertain the status of patents and licensing arrangements.

3. Evaluate the alternatives:

   - a. Establish the technical feasibility:

     - (1) Conduct laboratory studies to establish or confirm behavioral characteristics and/or design parameters.
     - (2) Confirm the feasibility by pilot plant studies when technically or economically justifiable.
     - (3) Demonstrate the feasibility by a full-scale subsidized project when technically or economically justifiable.
     - (4) Utilize mathematical models to better understand the influence of multiple variables and to optimize process designs.
     - (5) Analyze and evaluate test and operational data of others.
     - (6) Establish the relative reliability of the alternatives.

   - b. Establish the economic feasibility:

     - (1) Compare estimated capital costs.
     - (2) Compute and compare probable operation and maintenance costs.
     - (3) Utilize system optimization techniques for establishing the most economical system.
     - (4) Obtain performance guarantees, where applicable.

Considerations particularly applicable to the use of new apparatus, instruments, machines, and other equipment items are as follows:

1. Check the reputation and experience of the supplier/developer:

   - a. Record of service
   - b. Technical assistance available
   - c. Breadth of experience in related equipment
   - d. Depth of experience with subject equipment.

2. Establish the fundamental principles governing performance:

   a. Performance and design parameters
   b. Effect of scale on design and performance
   c. Influence of operating variables on performance, e.g., temperature, pressure, velocity, interferences
   d. Limits of application, e.g., hydraulic capacity, material concentrations.

3. Evaluate the experience record of the equipment (test data from pilot, demonstration, or similar applications):

   a. Compliance with design requirements
   b. Operating problems
   c. Dependability of service (percent outage)
   d. Maintenance record
   e. Serviceability.

4. Confirm the economics of application:

   a. First cost
   b. Operating cost
   c. Annualized basis for comparison with other alternatives.

5. Determine the status of patents and licensing arrangements.

Not infrequently, defining the problem is the most challenging part of solving the problem. The impact on the environment of industrial wastewater effluents, for instance, may be highly complex and in some cases subtle. A single wastewater effluent has been known to create oil pollution, be toxic to aquatic life, impart taste to the water and to the flesh of both finny and shell fish, deplete the natural water dissolved oxygen supply, impart color, deposit solids, cause obnoxious odors, corrode hydraulic structures, increase the receiving water temperature adversely, and add nutrients which stimulate undesirable aquatic growths. Thus, it should be obvious that considerable care must be taken to clearly define the pollution control problem. A sound definition of the problem is required to assure that the proposed solution considers the complete problem, not just the superficial manifestations of the problem.

Information should be collected so that the variability of the quantity and quality of the effluent can be statistically characterized. This is necessary because pollution originates from a multiplicity of sources, even in the simplest plant, and varies in quantity and character from time to time. Unusual or abnormal pollution discharge situations frequently occur, depending on the size and complexity of the facilities involved. Because of these expected abnormal occurrences, the pollution control facilities should be designed to handle the "normal abnormalities" in addition to the base load.

The need for effluent quality change or control may be determined by environmental considerations or by regulatory standards. Most modern environmental quality control laws call for the determination of quantitative environmental quality criteria acceptable for different specific uses and for the establishment of quality standards (based on quality criteria) to protect stipulated proposed uses.

Variations in natural phenomena, can influence abatement requirements. For example:

-- The flow in fresh water streams normally varies from season to season within a year and also from year to year. In the United States, it is becoming common practice to require the design of water pollution control facilities to protect the stream for the minimum seven day average flow that occurs at a frequency of once every ten years.

-- Natural phenomena can influence the displacement of water in estuaries and bays and therefore influence the design basis for marine disposal facilities.

-- Seasonal temperature variations can influence pollution abatement requirements.

Thus, the variability of the environment to dilute or purify must be considered in establishing the design basis and in evaluating new technology for pollution control facilities.

Well designed applied research and development laboratory efforts can produce meaningful information for selection of feasible processes and determination of basic design parameters. Applied research and development effort is generally required because each problem is individual. This individuality makes it risky to attempt a "pat" solution. Pollution control seldom has pay-out to cover errors; therefore, additional costs to insure a sound solution are insurance against expensive failures. If unusual process-control, materials-handling, or corrosion problems are indicated by the laboratory studies, pilot-scale facilities should be operated to reject or confirm the existence of the suspected problems.

The economic evaluations should be conducted utilizing techniques that will assure selection of least-cost designs from the technically feasible systems available.

Achievement of the least-cost system requires:

1. Best choice of materials and equipment
2. Most economical arrangement and design
3. Lowest cost financing arrangement
4. Sound operation and maintenance programs:
    a. Selection and training of competent operation personnel
    b. Monitoring facilities to establish and identify process loadings
    c. Adequate and timely maintenance and available spare parts to assure effective and reliable operations
    d. Management support of operating personnel.

The engineering design of pollution control facilities frequently involves special problems relative to corrosion, scaling, or clogging that require special materials of construction, instrumentation, or equipment. Problems which at first glance seem to be simple frequently become highly complex.

A few illustrations, briefly summarized, will illustrate both the simplicity and the complexity of adapting new technology.

A paper mill was confronted with the necessity of reducing its organic wastewater load by 99 percent or more (2). It had two combination aerotron-settling tank units operating in parallel, that were achieving 80 to 90 percent BOD_5 removal. Simple laboratory batch treatment tests were run for the purpose of establishing the kinetics of BOD removal, the oxygen requirements, and the activated sludge settling characteristics for both the raw wastewater and the treated effluent. This fundamental information indicated the possibility of achieving the desired results by operating the existing system in series. Minor piping changes were made. The series operation acheved the needed results, without equipment change, economically and reliably. Thus, the proper application of fundamentals made it possible to use a new technology to solve a difficult problem at a fraction of the anticipated cost.

In another case, a petrochemical plant was under orders to achieve a consistent effluent quality requiring about 97 percent average BOD_5 removal (3). An analysis of the effluent quantity and quality showed significant variability (See Figure 1) and small-scale continuous pilot plant operation showed a significant variation in treatment characteristics (See Figure 2). The variability in BOD_5 loading and in treatment characteristics indicated that a problem existed relative to achieving the desired treatment efficiency on a consistent basis. Consequently, a computer program was devised to predict the portion of the time that the single-stage or the two-stage activated sludge process could achieve the desired effluent quality. Since the variability in concentration and treatment rate occurred on a randomized basis, it was assumed that these variable could be combined on a randomized basis. Under these assumptions, it was demonstrated that a two-stage system was more reliable and possibly more economical. Since the use of a two-stage system was considered to be new technology, two small-scale pilot plants were operated in parallel. One was single-stage and the other was two-stage. The pilot plant results confirmed the results of the computer program. Thus, new predictive and new effluent treatment technology was confirmed experimentally. Full-scale results have confirmed the experimental results.

A large municipality with a conventional activated sludge plant reported operating results indicating high phosphate removal at times and phosphate release at other times (4,5). A research and development project was undertaken to determine the cause of such variability and to establish the feasibility of consistent high level phosphate removal. A comprehensive sampling and analysis program covering raw wastewater, intermediate, and treated effluent was undertaken. In addition, batch treatment experiments, small-scale continuous pilot plant experiments, and full-scale plant experiments were completed. Evaluation of the test data indicated that the mixed liquor flow pattern and the dissolved oxygen content of the mixed liquor were the primary factors influencing phosphate removal. Phosphate could be removed or released, at will, by changing the operating conditions (See Figure 3). The control system achieved high phosphate removal with remarkable consistency. There is no proof at this time that activated sludge treatment, alone, will achieve the desired 90 to 95 percent removal of phosphate in any more than 3 or 4 municipal sewage treatment plants in the United States. However, parameters and a methodology have been established that will make it inexpensive for municipalities to determine the feasibility of achieving high phosphate removal at low cost.

Adequate dissolved oxygen control is essential to reliable phosphate removal. Tried and proven dissolved oxygen monitoring and control equipment is now widely available. The automatic computerized control of the activated sludge process is now feasible (6).

A thorough study of the quantity, character, and frequency of occurrence of combined sewer stormwater overflows for Washington, D. C., has demonstrated that the use of new storage and treatment technology can solve the stormwater overflow problem at a fraction of the cost of sewer separation (7). Not only is this approach less expensive but it also provides treatment of all the stormwater. Thus, the suspended solids, BOD$_5$, and nutrient pollution from stormwater is greatly reduced overall, and dramatically reduced at times of storms.

An oil refinery, with a separator effluent BOD$_5$ of 30 to 90 mg/L, was ordered to reduce its BOD$_5$ by 87 percent (8). Laboratory bench-scale tests revealed that either activated sludge or activated carbon could achieve the required BOD$_5$ removal and that each could assure high removals of oil and phenol. Therefore, bench-scale tests were conducted to develop design parameters for alternative treatment systems. The use of these design parameters revealed that a sand filter, activated carbon, centrifuge sludge dewatering system was more economical than activated sludge. This was due primarily to space limitations in the refinery and the lesser space requirements of the activated carbon system. The economics of the activated carbon treatment system justified the use of the new technology. However, in the case of another oil refinery in the same river basin the conventional activated sludge system proved to be the more economical and preferable system.

A wood products plant had a highly-colored, high BOD$_5$ effluent requiring about 95 percent BOD$_5$ removal (9). Because of anticipated future requirements on color removal, studies were initiated to determine the feasibility of using bark and waste wood products for manufacturing activated carbon and then using the activated carbon for wastewater treatment. The activated carbon could achieve the required BOD$_5$ removal and could produce a substantially colorless effluent. However, the high activated carbon requirements and the new technology involved in activated carbon manufacture and regeneration made the application of this new technology both uneconomical and risky. Therefore, activated sludge was provided even though the treatment does not provide significant color removal. In this case, the waste activated sludge was very difficult to dewater. Bench-scale and pilot-plant test data indicated the technical feasibility and economic advantages of using the new electrolytic cell type of sludge thickening. Although initial full-scale operating results were disappointing, the equipment is now meeting its performance guarantees.

Pollution Abatement

The technology of pollution prevention is not new. The first draft of a manual on the subject for the petroleum industry (in behalf of the American Petroleum Institute) was prepared by the author nearly 20 years ago. Although the basic concepts are not new, it is believed that a new technology is emerging for industrial pollution control.

This new technology is predicted because of:

1. Higher costs for waste control due to more restrictive regulatory requirements on all aspects of environmental protection (water, air, and land) and escalating construction and operation costs.

2. The possibility of Federal law that will require a detailed evaluation of the potential impact of waste materials on the environment prior to approval of construction and/or operation of facilities manufacturing new products.

3. The possible establishment of raw waste and effluent standards for different manufacturing process operations based on a standard of "good practice" such that those producing raw waste greater than that of "good practice" must provide a higher degree of effluent treatment to meet the effluent standards and those producing raw waste less than that of "good practice" may provide a lower degree of effluent treatment to meet the effluent standards.

Higher pollution control costs, the likelihood of more stringent pollution control requirements, and possible incentives for in-plant control of pollution are each forcing more industries to look at the entire pollution generation-effluent treatment system rather than at effluent treatment alone. In the case of new facilities, the escalation of the costs of handling, treating and disposing of process losses and by-products from practically nothing to a very significant positive value is changing the economic criteria controlling the details of industrial process and plant design.

The emerging new pollution prevention technology will be based on the following concepts:

1. Minimize process losses and by-product formation at the source.

2. Maximize the recovery and reuse of those product and by-product losses that cannot be eliminated.

3. Provide effluent treatment only for that which can be controlled or handled in no other way.

The ultimate objective of preventive measures is the establishment of a closed loop system producing no wastewater discharge. Several industries in the United States have recently achieved this objective (10). The wood products plant, referred to earlier, has conducted its pollution abatement program in accordance with the above concepts. Today they are recovering and marketing materials that just a short time ago created serious water pollution.

Most industries will be unable to achieve the closed-system objective; however, all have the potential of significantly reducing pollution by preventive measures.

The various preventive (i.e., in-plant) measures that can reduce pollution are:

1. Process design modifications, (e.g., overall economics vs. unit operations economics; continuous vs. batch processing; loss-control devices; reagent substitution; surface condensers vs. barometric condensers).

2. Recovery and utilization, (e.g., downgraded use of chemicals; product recovery and reuse).

3. Engineering design considerations, (e.g., water conservation; waste segregation; used-water recycle; leakage control devices and systems).

4. Local equalization, pretreatment, or disposal.

5. Operation control, (e.g., automatic vs. manual control).

6. Good housekeeping, (e.g., employee relations programs).

Industry is in a unique position in that it has numerous and varied alternatives available for solving its pollution control problems. It has such alternatives because it has control of its system from source to disposal. Industry can control what it produces, where it is to be produced, the process that it uses for production, the manner in which it handles its process losses and by-products, the reliability of process and mechanical designs, and how it handles and disposes of its wastes. Thus, industry may choose to minimize pollution control costs by being selective about the location for its plants or special processes. It may choose to control pollution at its source by choice of basic process, by choice of continuous vs. batch processing, by loss recovery and recycle, by by-product utilization, or by special process and/or mechanical designs. It may choose to simplify or minimize costs by segregating wastewater streams, by utilizing separate sewerage systems, by providing used-water recycle systems, by equalization, or by pretreatment. It may control losses by providing operational aids and by enforcing good operation practices. It may choose to treat and dispose of its wastes utilizing its own on-site facilities, or it may utilize a public system.

The kind of pollution control facilities provided depends on the nature of the problem, the permissible quality of the effluent, and the required reliability of performance. The best system can be evolved only if the interrelationships of the entire system, including the manufacturing facilities, are properly considered and evaluated. It must be remembered that air pollution control may result in a water pollution control problem and that the correction of the water pollution control problem may create either an air pollution or water pollution problem, and so on "ad Infinitum."

Thus, the potential for the development of a new technology for industrial water pollution control should be apparent.

In order to identify the potential of pollution reduction by one or more of the measures above, it is necessary to conduct detailed in-plant surveys to identify the source, quantity, quality, mode of occurrence, and variability of wastewater sources. The in-plant studies for the Humble Oil and Refining Company at their Baton Rouge, Louisiana, refinery (11) is a good example of the kind of program needed to accomplish in-plant pollution reduction objectives.

Pollution prevention at the source is not as well adapted to sanitary wastewater as to industrial wastewaters. However, the conversion of "hard" synthetic detergents to "soft" biodegradable detergents is equivalent to reagent substitution for industrial processes and indicates the trend of the times.

Environmental Protection

The technology of Environmental Protection can be enhanced significantly if current trends in the United States continue. These are the development of new technology for integrated river basin water quality management and improvement in the technology of governmental pollution control administration.

The development of objectives, goals, and tasks and of master plans for both immediate and long-range implementation for inter- and intra-state river-basin agencies show considerable promise for optimizing the use of water resources in the United States. Preliminary studies (12-16) have established a methodology for evaluation of alternatives and indicate that there is, in fact, a least-cost regional or basin solution to the water quality preservation problem. The more widespread use of this emerging new technology may be universally beneficial.

The administration of pollution control law must be reasonable, equitable, and credible. The deficiencies of past practices in this regard are being recognized. Reasonableness, for instance, is demonstrated by requiring only that which is attainable and enforceable. Equity is demonstrated by establishing and enforcing policies such that each polluter bears his fair share of the burden of attaining and maintaining clean waters. Credibility is demonstrated by persistently and consistently enforcing that which is attainable and enforceable.

The reasonableness, equity, and credibility of enforcement is intimately related to the technical aspects of pollution control. Therefore, the administrative policies should be carefully considered and clearly defined so that their technical relationships can be understood and uniformly applied by all administrators.

Some States in the United States are preparing comprehensive administrative manuals to assure consistency in administration of enforcement policy (17).

Those who pass new legislation and those who must administer pollution control law should carefully consider the fundamental concept of incentive There should always be incentive to control pollution as close to its source as possible. There should be incentive, other than drastic shut-down of operations, to abate rather than create pollution.

It is believed that the incorporation of new pollution control technology in process design and control is essential to attain and/or maintain desired water quality. Therefore, the development and use of new technology should be encouraged.

There is no substitute for knowledge of fundamentals, for the experience and skills required to apply that knowledge, and for sound judgment in the incorporation of new pollution control technology in process design and control. Nevertheless, the availability of a methodology for minimizing the risk in incorporating new technology should encourage the development and use of such new technology.

The concepts and guidelines discussed herein have been very useful to the author in incorporating new technology in process design and control. It should be understood that the specific steps to be undertaken and the thoroughness of the effort should be controlled by the magnitude and complexity of the project. It is hoped that these concepts and guidelines will be helpful to others and in doing so will stimulate progress.

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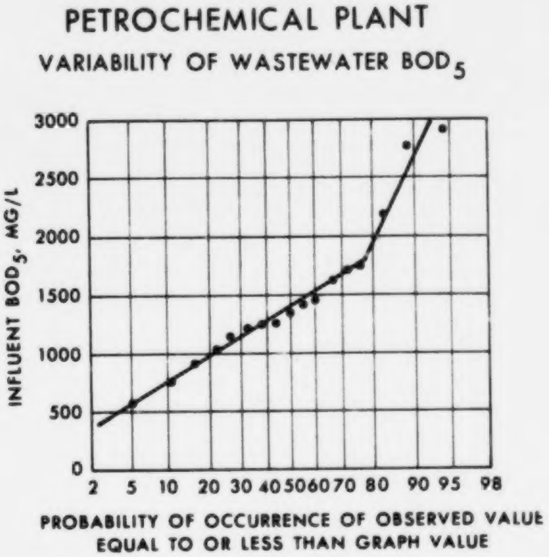
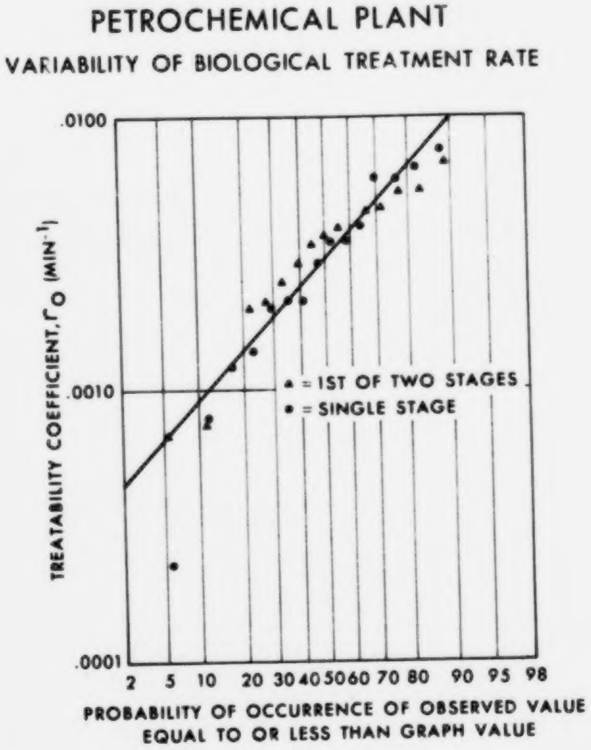

PETROCHEMICAL PLANT

VARIABILITY OF WASTEWATER BOD_5

Figure 1


PETROCHEMICAL PLANT

VARIABILITY OF BIOLOGICAL TREATMENT RATE

Figure 2

PHOSPHATE REMOVAL IN FULL-SCALE ACTIVATED SLUDGE WITHOUT CHEMICAL ADDITION

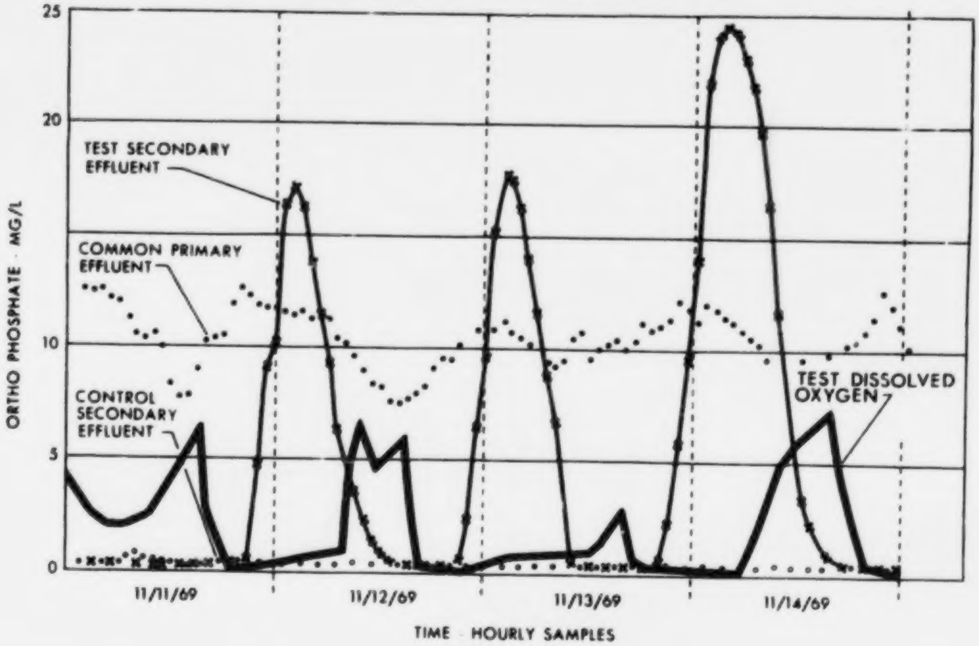
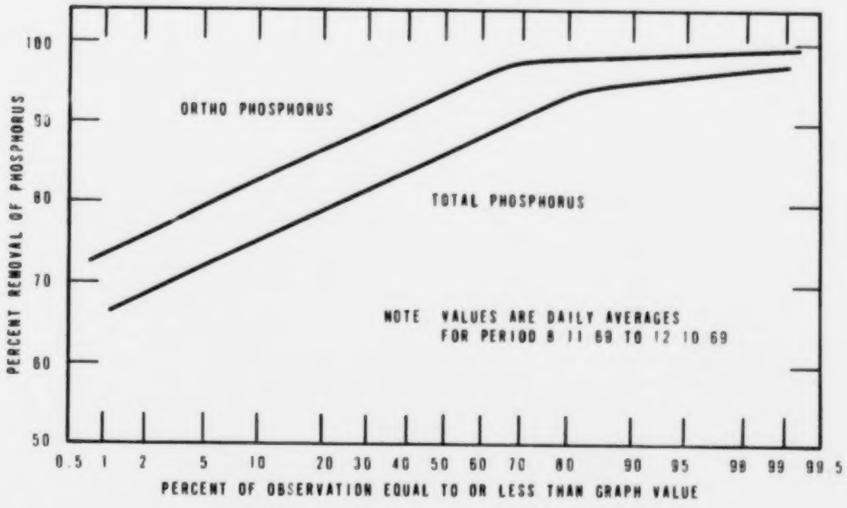


Figure 3



CONTROL ACTIVATED SLUDGE SYSTEM
PHOSPHORUS REMOVAL VARIABILITY

Figure 4

EVALUATION OF NEW WATER POLLUTION CONTROL TECHNOLOGY

By Walter A. Lyon
Director, Bureau of Sanitary Engineering
Department of Environmental Resources
Commonwealth of Pennsylvania, USA

Government has a primary responsibility to correct environmental injuries and plan for a wholesome environment. This is why it must play a key role in evaluating and advancing new water pollution control technology. Pollution problems are largely due to technology which is planned and land development which is allowed to proceed without considering environmental effects. This means that government also has a role to help reshape technology so as to make it more harmonious with nature.

This paper touches on recent improvements in water pollution control technology that have shown promise, and then discusses government's role in evaluating and reshaping technology.

Industrial Wastes

Coal Mine Drainage--Recent revisions in Pennsylvania's water pollution control law which placed drainage from coal mines on the same regulatory basis as other kinds of industrial wastes has resulted in the construction of treatment facilities to reduce pollution from coal mine drainage(1). Lime treatment for pH adjustment, precipitation, aeration, and clarification are used in order to remove acidity and iron from mine drainage. State standards require the discharge contain no net acidity and a total iron content of less than 7 mgle. Table I shows performance data concerning five typical plants.

Some mine drainage treatment systems use novel approaches. In searching for neutralizing agents less expensive than lime, some mine operators have turned to limestone. But, the ferrous ion in the mine drainage precipitated on the limestone, coating it and rendering it inactive. To overcome this problem, the limestone chips were placed in horizontal rotating cylinders which provided sufficient attrition to keep the limestone "clean."

Where lime is used as a neutralizing agent, significant quantities of unreacted lime appear in the sludges. To eliminate this waste and reduce chemical costs, some mine operators have begun recirculating sludges. Recirculation of sludges works very well and has an added benefit of concentrating the sludge. Typical solids concentration in non-recirculated sludges is about 5% by volume. The concentration of solids in recirculated sludges is about 30% by volume.

In some locations treatment plants are used to neutralize the entire flow of streams which had been polluted by acid and iron discharges from abandoned coal mines. On the North Branch of Slippery Rock Creek in Pennsylvania the entire stream is passed through a treatment plant (during periods of normal flow) for neutralization and clarification and in other ceases, lime feeding equipment is installed over the stream and lime is discharged directly into the stream. The precipitate is removed in earthen basins.

Water Pollution from Solid Wastes Disposal--The increasing attention to the environmental effects of solid waste disposal has led to the finding that many solid waste disposal sites cause water pollution, particularly ground water pollution problems(2). Sanitary landfills using earthen cells which surround the compacted refuse are used frequently. In a number of instances collection and treatment of leachate from sanitary landfills is required in order to allow the use of the landfill site. In some instances synthetic membrane liners for the landfill are required in order to intercept and collect the leachate.

Spray Irrigation--Spray irrigation as a means of organic industrial waste disposal is being practiced widely(3,4). It has been highly successful where careful consideration is given to soil characteristics, hydrogeology, vegetation, and spray field management in order to prevent surface and ground water pollution. The fertilization characteristics of some waste effluents has provided a substantial supplement to cattle pasture productivity.

Pulp and Plating Wastes--The activated sludge treatment process has been important in the successful treatment of pulp and paper mill wastes(5,6) and phenolic wastes. In the management of plating wastes, the development of integrated systems where wastes are treated at the source has been found increasingly successful(7,8). These systems minimize the need to discharge heavy metals from plating plants and have been effective in reducing pollution from this source. In these systems chemical are added to rinse waters as a part of the process allowing for more extensive reuse before rinses are exhausted and sent to the waste water treatment system.

Pollution Incident Prevention--In spite of the application of widespread successful industrail waste treatment practice throughout Pennsylvania, there continue to be a significant number of pollution incidents caused by human, maintenance, or operational failures. In order to prevent this problem, the state has implemented a Pollution Incident Prevention Program which requires industrial plant management to study production and waste management systems in order to make sure that plant design, operational procedures, and personnel training programs designed to anticipate and prevent pollution incidents(9,10).

The study and report required of each water-using industrial plant must include an analysis of possible accidents which might occur during transportation, storage and processing of raw materials, intermediate, and finished products, materials and fuels(11). The possibility of breakdown of treatment plant equipment must be considered. The plan must include a program of routine inspections and preventive maintenance, personnel training, procedures for minimizing damage from possibe pollution incidents and an analysis of past pollution incidents. Experience so far has shown that 1/3 of the pollution incidents during the past five years in Pennsylvania were caused by production process failures and not treatment systems failures.

Deep Well Disposal--The disposal of wastewaters in deep wells has(12) been practiced on a limited basis and found to present many problems. Pretreatment costs and system maintenance are expensive and some wells have already been abandoned.

Sediment Control--There is an increasing amount of interest in sediment control from construction and agricultural operations. Technical and government program methods are being developed and have been quite successful in some instances(13,14).

Municipal Wastewater Treatment

Tertiary Treatment--Increasing water usage and population growth in and around urban centers have made it necessary to provide tertiary-level treatment, particularly in cases where municipal sewerage systems discharge to small high-quality streams. In many instances, tertiary treatment is necessary, not only to reduce the organic wasteload on the streams, but also to remove phosphates from the effluent of the wastewater treatment plant to control the growth of aquatic plants(15,16). Eighty percent (80%) phosphate removal is required in a number of instances throughout the state. Chemical treatment with lime or alum for phosphate coagulation with clarification is the most common process used. Detroit, Michigan plans to use pickling liquors from a nearby steel mill as a coagulant(17).

Aerobic Digestion--Waste activated and increasingly primary sludge, aeration, has been adapted from package plants to provide for more nuisance-free solids disposal(18,19). Larger plants, such as Denver, Colorado and the Hyperion plant at Los Angeles, are currently practicing aerobic sludge digestion to soluble-ize approximately 40% of the sludge solids with a waste liquor that can be effectively reprocessed.

Tube Settlers--The installation of tube settlers in existing clarifiers has been found quite successful in improving the efficiency and capacity of clarification systems(20).

The Use of Polymers--Chemical polymers have been used successfully as coagulant aids in wastewater treatment processes, particularly in cases where existing treatment efficiency both in terms of BOD and suspended solids removal needed to be upgraded significantly. In most cases, experiments with various types of polymers was necessary in order to select the ideal polymer for the specific treatment plant. Polymers have also been found successful for increasing the carrying capacity of sewers.

Plastic Media--The use of plastic rather than stone media in connection with trickling filters has allowed significant economies and savings in space when installed in specially designed units and has in some instances increased efficiency of existing filters.

Spray Irrigation--Experiments with spray irrigation of secondary effluent has been successful(21). The success of the process is largely due to suitable soil and geologic conditions which provide significant bacterial action and exchange capacity for the removal of phosphates and other pollutants. The process has resulted in enhancement in growth rate of forest and agricultural crops as well as providing recharge of local ground water.

Joint Treatment--Joint treatment of industrial wastes with domestic wastewaters has gained increasing favor. In some treatment plants the industrial waste load exceeds the municipal waste load. When such combination of treatment is being applied, careful analysis is necessary in order to determine the effect of the industrial waste on the collection system and the wastewater treatment process. Pre-treatment prior to discharge to the sewage system is necessary in the case of some wastes.

Plant Operation and Waste Load Monitoring--Increasing attention is being given throughout the United States to operator training and certification as the expertise of the operator is crucial to the success of the waste treatment process. Twenty-seven states now have mandatory operator certification and twenty more have voluntary programs.

Many treatment plants have become hydraulically and organically overloaded as a result of rapid urban and industrial growth. Increasing emphasis is being placed on careful monitoring of waste load trends and advance planning to provide needed conveyance and treatment plant capacity on a timely basis.

Water Pollution Control

Systems Techniques--The use of modern systems techniques has greatly enhanced water pollution control practice in the United States(22). Systems techniques are now used in the simulation and modeling of treatment plant design and assimilative capacity of estuaries and streams. Data systems to improve state-wide water pollution control management are being used and expanded in Pennsylvania, Michigan, New York and an increasing number of states.

Government water pollution control programs can primarily be viewed as information processing efforts. The methods used to handle this information are usually antiquated and as a result there are significant delays in responding to pollution problems. Pennsylvania is in the process of carrying out a demonstration water quality management information system research and development project under the sponsorship of the Environmental Protection Agency which is designed to overcome these defects and use modern systems techniques in the management of water pollution control programs(23,24). Figure 1 shows the systems modules which are in the process of being designed, programmed, and implemented.

The shortest response time between the recognition of pollution problems in a major water body and its solution is between fifteen and twenty years. Adequate forecasting systems should shorten this response time in the future to prevent interim degradation. Most waters remain polluted because of this long response time.

Comprehensive water quality management information systems will greatly enhance the speed and precision with which decisions may be made in the water quality management field. Such systems provide the water quality manager with current and accurate data and permit forecasting of water quality problems and the execution of "before the fact" preventive actions or plans.

In Pennsylvania it recently became necessary to manage 200 miles of river on a real-time basis(25). A sudden release of impounded water from an abandoned coal mine resulted in the discharge of 150 tons of acid per day into the West Branch of the Susquehanna River. By use of mobile laboratories equipped with radio communcations, state water management personnel were kept in constant touch with water quality conditions. They were able, by the addition of lime and sodium hydroxide at various river stations and management of dam releases, to effectively manage the quality of the river over a period of six months, preventing serious water quality degradation.

The Role of Government in the Development of New Water Quality Management

Technology

While the historical role of government in water pollution control has been in the regulatory field, it is essential that government also provide an important stimulus for developing and implementing new technology by making known research needs and funding research programs and projects(26). One of the regulatory functions is the review of engineering designs of collection and treatment systems. In carrying out this review function, standards based on existing technology are established and used which are usually quite conservative to assure soundness of investment and performance. At the same time, government has a continuing responsibility to evaluate new technology and modify standards as adequate pilot and prototype data become available. Problems often arise when someone proposes a new untried process and hopes to experiment with public (non research) funds to determine its feasibility. In Pennsylvania we have taken the postion that research and demonstration funds should be used for purposes of experimentation, but we have occasionally found that the proponents of new concepts have wanted to experiment with the funds of municipalities which were in the process of designing a sewage treatment plant in order to abate pollution. We have permitted such experimentation as long as the experimenter is willing to bear the financial risk of the experiment by placing funds into escrow which might be needed to convert the process to a conventional process should the experiment fail. Under this policy, a number of new processes have been developed.

The Role of Production and Service Technology in Pollution Control

One of the major reasons for the increase of pollution problems in industrialized countries is that production and service technology have been allowed to develop with minor, if any, consideration given to their effect on the environment. The imposition of pollution control on production processes will often cause changes in production technology designed to minimize pollution problems.

Many industries are learning to recycle their wastes to minimize the use of water and to recover or reuse materials which are previously discharged in the form of pollution. An outstanding example of such a production change has been the complete revamping of the pulp and paper processes at the Hammermill Paper Company in Erie, Pennsylvania. At the cost of approximately $30 million this plant changed its process to increase production of pulp by 50% and (at the same time) reduce by approximately two-thirds its organic and color waste loads. As a result of this change the Hammermill Paper Company will be sending its reduced waste load to the City of Erie Sewage Treatment Plant for treatment where the municipal wastes will provide the nutrients necessary for treatment and the treatment process provides for a very high degree of treatment prior to discharge to Lake Erie. As pollution control programs expand and affect an increasing number of industries, it is likely that we will see similar responses in industrial production and service technology in industrialized countries.

The Need to Blend Water Pollution Control, Production, Service Technology, and Land Use Planning and Control

The Waste Impoundment Problem--Unless water pollution control activities are conducted in harmony with industrial and urban needs they can generate their own adverse externalities by creating new forms of pollution problems. One example is the rapid growth of waste impoundment lagoons as a result of Pennsylvania's water pollution control program. Between 1937 and 1970 Pennsylvania's industrial waste control law and program were geared to eliminate pollutional discharges. While this program has been quite successful in eliminating a great deal of fisible pollution from our surface waters, it did result in the growth of lagoons throughout Pennsylvania to the point where we now have approximately 2,000 of them. Many contain toxic chemicals, petroleum products, and other substances that may either cause ground water pollution or surface pollution incident hazards. A number of these waste impoundment structures have recently failed and caused serious pollution incidents. One such failure caused pollution of approximately 50 miles of the Allegheny River and another lagoon containing wastes recently failed causing oil pollution along 35 miles of the Schuylkill River and 13 miles of the Delaware River. The 1970 amendment to Pennsylvania's law has now allowed the state to initiate a program to eliminate these hazardous lagoons. This will make it necessary for many industrial processes to be modified to minimize the production of toxic or otherwise harmful wastes or else provide for a more satisfactory process for treating them.

The Effect of Municipal Wastewater Charges--The imposition of charges for industrial wastes discharged to municipal sewer systems has in some cases been helpful in modifying the processes used within an industry which have produced wastes. In any case, industries should be expected to bear their fair share of the cost of handling their wastes in municipal systems and where a significant share of plant capacity is reserved for any industrial plant, financial protection must be provided in the event the industry moves or ceases to use its portion of the system.

Waste Load Control--The state has recently imposed sewer extension and connection bans as a result of the uncontrolled expansion of sewer systems which result in overloaded treatment plants and hence more pollution. This is a new form of land-use control related to the control of pollution. Bans on sewer connections and extensions have been imposed on sewerage systems tributary to treatment plants which have become overloaded. In order to prevent this problem in the future, each Pennsylvania municipality has been asked to submit an annual report showing organic and hydraulic waste load trends. When the plant is within five years of reaching its capacity, the municipality must submit a schedule showing how it will proceed to provide the needed additional capacity within five years. If such a schedule is submitted, approved, and adhered to, additional extensions and connections are allowed--otherwise a ban is imposed.

Regional Systems--The state now has the authority to consider the establishment of regional wastewater management systems in the issuance of permits for sewage and industrial waste systems. A great deal of fragmentation in waste treatment has occurred because water pollution control programs have in the past emphasized the abatement of pollutional discharges. Increased attention is now being given in the United States and Canadian provinces to the regionalization of waste collection and treatment systems(27). This will result in improved economies, more efficient use of facilities, better supervision and service, and greater harmony with water use requirements. Such systems should be planned considering water supply and water development needs jointly and should support and enhance economic and social plans for the region. In order to control the fragmentation of waste management problems and reduce the response time between the issuance of orders by the state and construction of pollution abatement facilities by municipalities, the state is now considering legislation which would allow it to install and, if necessary, operate wastewater treatment facilities in the case of municipalities that do not wish to build them. These facilities will be financed by user charges in the same manner as locally constructed municipal systems.

Water pollution technology is rapidly growing to meet the challenge of a more wholesome and pleasing environment throughout our nation. Inasmuch as technology is largely the cause of pollution problems, its intelligent and discriminate application can and will eliminate and prevent pollution problems of the future.

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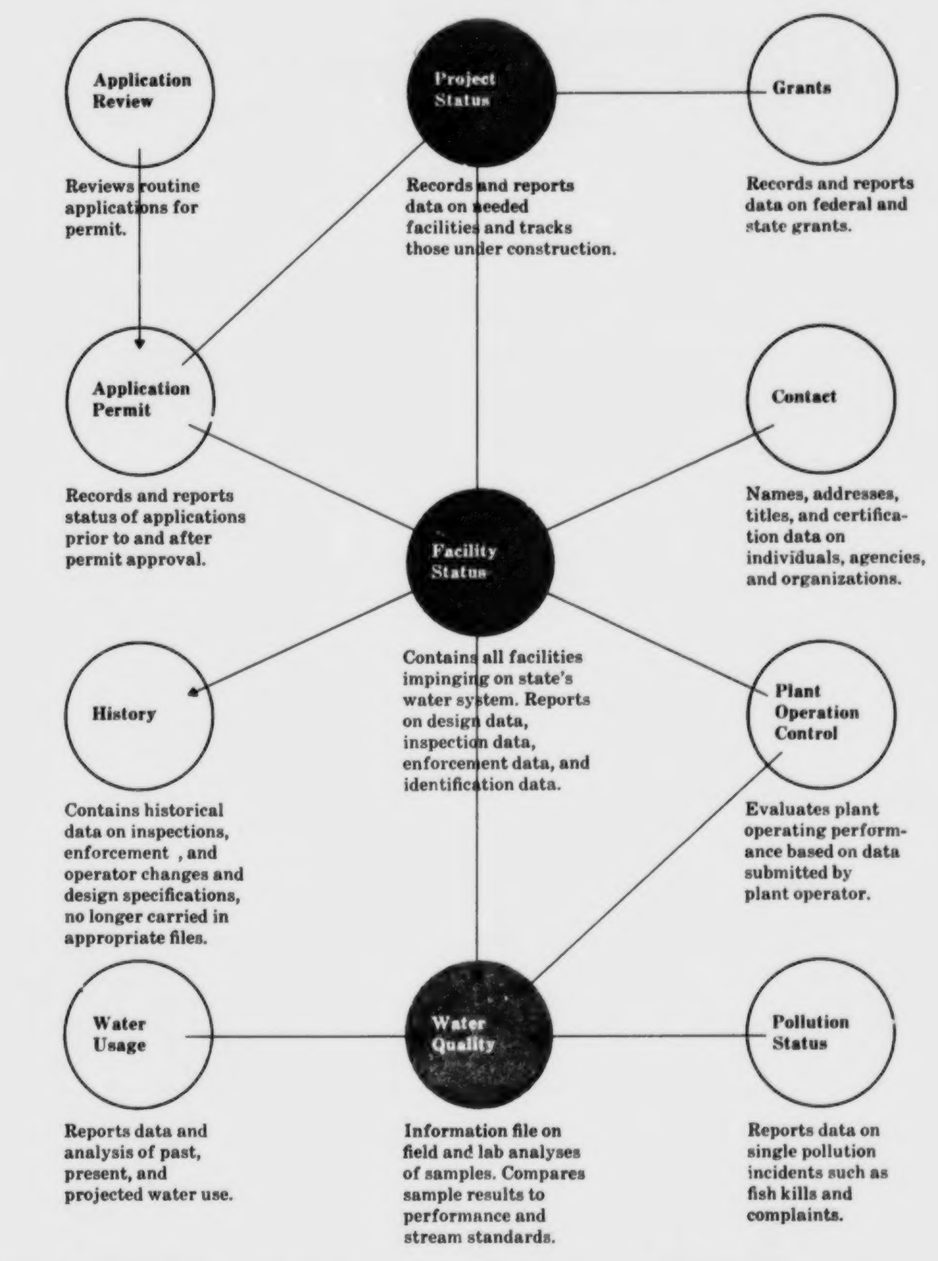

Application Review
Project Status
Grants
Application Permit
Contact
Facility Status
History
Plant Operation Control
Water Usage
Water Quality
Pollution Status

Water Quality Management Information System (system modules)

Application Review: Reviews routine applications for permit.

Project Status: Records and reports data on needed facilities and tracks those under construction.

Grants: Records and reports data on federal and state grants.

Application Permit: Records and reports status of applications prior to and after permit approval.

Contact: Names, addresses, titles, and certification data on individuals, agencies, and organizations.

Facility Status: Contains all facilities impinging on state's water system. Reports on design data, inspection data, enforcement data, and identification data.

History: Contains historical data on inspections, enforcement , and operator changes and design specifications, no longer carried in appropriate files.

Plant Operation Control: Evaluates plant operating performance based on data submitted by plant operator.

Water Usage: Reports data and analysis of past, present, and projected water use.

Water Quality: Information file on field and lab analyses of samples. Compares sample results to performance and stream standards.

Pollution Status: Reports data on single pollution incidents such as fish kills and complaints.

Figure 1

TABLE I

MINE DRAINAGE TREATMENT PLANT CHEMICAL ANALYSES
SURVEY SEPTEMBER--OCTOBER 1968

NOTE: All parameters are expressed in milligrams per liter except pH; turbidity (Jackson Candle Units), temperature (degrees centigrade), and settleable solids (milliliters per liter).

		Plant No. 1				Plant No. 2		Plant No. 3	
	PARAMETERS	Plant Influent	Aerator Influent	Aerator Effluent	Plant Effluent	Plant Influent	Plant Effluent	Plant Influent	Plant Effluent
FIELD	pH	5.6	8.3	8.3	8.3	7.4	9.2	4.1	10.6
	Temperature	17.5	17.5	17.5	17.5	DNA	DNA	DNA	DNA
	Dissolved Oxygen	5.2	4.9	4.7	6.6	DNA	DNA	DNA	DNA
LABORATORY	pH	4.7	7.0	7.2	7.7	7.2	8.4	3.1	10.6
	Alkalinity	-24			+114	+50	+58	-220	+108
	SO_4	2480			2450	905	765	506	652
	Turbidity	400			20	55	5	280	15
	Solids								
	Total	4790			5080	1680	1220	1060	1460
	Suspended	200			100	40	20	280	120
	Settleable	1.6			0	0	0	8.0	0.20
	Mg	87			76.5	19.8	18.0	35.0	4.8
	Zn	0.20			0.04	0.22	0.04	2.0	0.07
	Al	3.80			0.25	0.00	0.00	6.75	1.00
	Mn	2.70			1.58	0.90	0.35	2.65	0.21
	Ni	0.23			0.06	0.25	0.10	0.19	0.04
	Pb	0.04			0.12	0	0	0.14	0.08
	Fe Total	65.3	60.0	60.0	4.80	8.3	1.5	86	1.8
	Fe^{+2}	DNA	0.0	0.0	0	0	0	1.1	0
	Cu	0.04			0.10	0.01	0.04	0.18	0.35
	Cr	0.018			0.010	0	0	0	0
	Ca	208.0			240	52.8	51.5	59.8	210.0
	As	0			0	0	0	0.003	0

TABLE I--CONT'D

MINE DRAINAGE TREATMENT PLANT CHEMICAL ANALYSES
SURVEY SEPTEMBER--OCTOBER 1968

Note: All parameters are expressed in milligrams per liter except pH; turbidity (Jackson Candle Units), temperature (degrees centigrade), and settleable solids (milliliters per liter).

		Plant No. 4			Plant No. 5			
	PARAMETERS	Plant Influent	Neutralizer Effluent	Plant Effluent	Pond No. 2 Influent	Aerator Influent	Aerator Effluent	Plant Effluent
FIELD	pH	3.6	6.8	6.8	6.7	6.8	6.8	6.8
	Temperature	11.8	11.8	15.5	17.0	18.0	18.0	19.0
	Dissolved Oxygen	9.5	8.6	10.3	5.5	7.5	5.5	6.0
LABORATORY	pH	3.1	7.2	7.2	6.9	6.7	7.2	7.3
	Alkalinity	-220	+102	+64	+256			+236
	SO_4	1000		1070	1050			2500
	Turbidity	30		10	160			125
	Solids							
	Total	2000		2260	2400			1880
	Suspended	80		30	160			100
	Settleable	0.40		0	0.4			0
	Mg	44.8		44.3	58.8			63.5
	Zn	1.0		0.22	0.04			0.00
	Al	8.5		0	0.00			0.00
	Mn	1.80		1.68	2.05			2.08
	Ni	0.45		0.35	0.00			0.00
	Pb	0		0	0.00			0.00
	Fe Total	36.5	68	1.0	16.8	24.0	24.0	4.5
	Fe^{+2}	1.1	2.2	0	DNA	0	0	0
	Cu	0.10		0.03	0.05			0.03
	Cr	0		0	0.10			0.00
	Ca	118		188	176.0			182.0
	As	0		0	0			0

WATER POLLUTION IN THE NETHERLANDS

By Ir. K.C. Zijlstra
Director, Netherlands Government Institute
for Wastewater Treatment

The Netherlands is one of the most densely populated countries in the world. The land area is about 37,000 km^2. With a population of 13 million, it has a density of rather more than 350 inhabitants per km^2. This figure lies in the same order of magnitude as that of the State of New Jersey in the U.S.A. The area of New Jersey is a little more than half of the area of the Netherlands.

The Netherlands is a country abounding with water, it has a long coastline and great areas of the land surface are situated below the average sea level. A still greater part would be flooded during high water levels should storm tides occur. Therefore, throughout history, this necessitated the building of thousands of kilometers of dikes; dikes that must constantly be maintained and heightened; this process is still continuing (Zuiderzee-works and Delta-works). The primary object of these works has been to increase the safety factor against floods. The carrying out of these plans leads to a considerable shortening of the long coastline.

The Netherlands has a temperate marine climate, with soft rainy summers and likewise soft and slightly less rainy winters. The average annual rainfall is 720 cm. The wet summers are alternated by years with dry summers, with exceptions of some extremely dry summers. In winter the precipitation exceeds the evaporation, in summer this is not the case.

Because the water levels in this flat country must be regulated with great accuracy and there are few possibilities for storage of water, local water shortage may occur during the summer months in periods of great evaporation. These shortages have to be made up by water from the big rivers--the Rhine and the Meuse. In a quantitative way the Rhine is by far the most important water supplying river. It is to the Netherlands' advantage that the origin of the Rhine lies in Switzerland, where in summer the river is fed with snow melting from the glaciers. Therefore the rate of flow of the Rhine is not exclusively determined by the amount of rain falling in Western Europe. In dry summers the Rhine still has a reasonable flow. However in the case of a dry summer being succeeded by a dry autumn, the river flow may strongly decrease. The average annual flow of the Rhine is about 2200 m^3/sec., the lowest flow is below 700 m^3/sec. With such low flows the quality of the Rhine water is very poor. This is not to be wondered at, for the river passes through a densely populated catchment basin with heavy industry. In spite of the efforts of our eastern neighbors, they have not yet succeeded in taking anti-pollution measures at a sufficient rate, nor in keeping with the pollutional consequences of population and industrial growth.

The river Meuse is of less importance for its water supply to the Netherlands during dry spells. This river is exclusively fed by rain. Hence during dry periods in summer its flow is negligible in comparison with the flow of the Rhine. During bigger flows, however, the water

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quality in the Meuse is considerably better than in the Rhine. The drainage basin of the Meuse is far less densely populated and not industrialized to the extent of the river basin of the Rhine.

During the summer months great areas of the Netherlands depend on supply of water from the big rivers in order to compensate losses due to evaporation.

However there is still another important need of water to be met, i.e. the drinking water and industrial water supply served by means of public water works. Nowadays these waterworks in the Netherlands depend on groundwater for two-thirds of their needs and on surface water for one-third. The water delivery, however, is rapidly increasing and by the year 2000 the water supply is expected to be about 4 times as much as at present, two-thirds of which must be extracted from surface water and one-third from groundwater.

This means that the Netherlands must increasingly depend upon the use of surface water for the supply of high quality water. The management of the quality of this surface water is the primary aim in devising anti-water pollution measures. The best way to combat water pollution is as near the source as possible.

The situation in the Netherlands is typified by the estuarine region of the rivers Rhine and Meuse. Since great areas of the Netherlands are below sea level, the course of the water through the canals and ditches crossing these low regions can only be controlled artifically. Precipitation surpluses must be pumped out by drainage plants to the sea or to rivers having an open connection with the sea. The water displacements which can be accommodated in these canals and ditches, are small, the currents are slow and long stretches of stagnant water prevail. In such a system of surface water, transformations and sedimentations are liable to occur and substances that exert an unfavorable influence on the water quality may accumulate. Examples of this are fertilizers causing eutrophic and hypertrophic conditions. Other examples are heavy metals and persistent pesticides, and of the inorganic compounds, the chlorides may be mentioned. These are a particular nuisance, as natural infiltration adds chlorides also to the water in the low regions.

The peculiar geographic situation of the Netherlands, together with the great population density, and highly developed industrial expansion, particularly after the second world war, necessitate our country putting up a fierce resistance against a further increase of the pollution load on the surface waters. It is obvious that this also applies to the assortment of waste substances that are conveyed by the Rhine, our most important supply of water.

The surface water quality in this country in general is not high. Already much data have been accumulated and much research work been carried out, although the results are not yet widely disseminated.

The care of the water is a matter which has never been unfamiliar to the Dutchman. The fight for better water, however, has not yet been won. The implements to fight water pollution already exist, but they are still new and need continuous improvement and criticism. Nor is everybody accustomed to the thought that, according to a Dutch saying, "the dearer it is, the farther it goes."

Only recently legislation governing water pollution control has been implemented and the Law against Pollution of Surface Waters came into force on December 1, 1970. This is the first regulation applicable to the whole of the Netherlands. Those by-laws of provinces and waterboards already existing will have to adapt themselves to this regulation within the next 4 years.

A curious thing is that in the Netherlands, quite a lot could be done against water pollution by virtue of ordinances of a more local nature even without there being a national law. Important sources of water pollution have been tackled in this way and the Government has always highly approved of these activities, and also given financial support.

On January 1, 1970, there were 441 municipal sewage treatment plants in the Netherlands serving 7 million population-equivalents. 58 plants are now under construction serving almost 4 million population-equivalents. It appears from these figures that in the Netherlands sewage works with a greater capacity are now being built.

The fact is that many of these existing sewage treatment plants are moderately sized because they had been originally built for smaller rural settlements (500 to 5,000 population-equivalents); these plants being of the oxidation ditch type, a purification system which was developed in the Netherlands. A number of big cities like Amsterdam, Utrecht, Eindhoven, Leeuwarden and Enschede do make use of big biological sewage treatment plants.

In addition to the above mentioned sewage purification works there are, in our country also a number of plants for sanatoria, military barracks and isolated industries; altogether about 100 with a total capacity of 650,000 p.e. One of these plants has been built for the industry complex of the D.S.M. (Dutch State Mines) with a capacity of 500,000 p.e.

Most big cities in the Netherlands are situated along big rivers or near the coast. Their sewage is still discharged raw, without passing through a treatment plant. To ensure water quality improvement in these big watercourses, the so-called "governmental" watercourses, is a task for the federal Government.

One of the first purposes of the Government is to take up the back-log of building sewage treatment works along these governmental watercourses by applying the rules that are prescribed in the Law against Pollution of Surface Waters. Starting point of the new law is a prohibition of discharging pollution matter into surface water without a permit. In the permit, conditions regarding the purification measures to be taken can be laid down, i.e., that all discharges into governmental watercourses will only be admitted after biological treatment. If necessary, further conditions may also be stipulated. While building plants for the bigger cities situated along governmental watercourses, efforts should be made towards connecting to them as many small residential nuclei as possible in order to concentrate as much as possible the purification process and its control into big units.

The new law prescribes that every five years the Minister of Public Works and Water Management, who is charged with enforcement of the law, fix an indicative more-year program for water pollution control in our country. These programs will show the priorities and the progress that has been made.

To prepare these 5-year plans the minister has set up working committees for the various big rivers; these working committees being charged with drawing up water pollution control schemes. Pollution control plans have already been completed for the rivers IJssel, Nederrijn-Lek and Meuse.

For towns and industries which do not discharge into governmental watercourses, similar plans are being prepared by the provincial boards. In due course all these plans are to be combined in a national plan. The Government Institute for Wastewater Treatment plays a prominent part in coordinating the different plans.

The battle for better surface water quality cannot be won, however, by merely making plans; the plans have to be executed and financed, and there is always much resistance. The Dutch law however supplies a means to overcome this obstacle. While drafting the law in parliament the principle has been accepted that "the polluter pays" to an extent proportional to the load of discharged pollution. This principle is generally valid, so it applies to the discharges of domestic sewage as well as to industry.

Anyone who discharges polluting matter into surface water, whether after advanced treatment or not, depends on the capacity of this surface water to eliminate the discharged matter somehow or to convey it, or--let us not forget this--to camouflage it. The ability of the surface water to achieve something in this respect is looked upon in the Netherlands as a common property. Anyone who uses it--as at present cannot be done otherwise--by discharging polluting matter into it, ought to pay. The money that flows into the exchequer must be used to grant financial aid to those who take anti-pollution measures.

This principle sounds simple. But how is it practiced? By what standards must the payment for sewage discharge be judged? This matter was given due consideration in the Netherlands and after much deliberation the following summarized conclusions were arrived at:

1. The following must be fought by stringent discharge conditions:
   (a) overloading of the surface water with oxygen-utilizing substances;
   (b) the discharge of inorganic salts and substances that cannot be decomposed by biological processes;
   (c) the discharge of toxic matter, along with heavy metals and pesticides;
   (d) the discharge of such quantities of hot (cooling) water, that the natural fluctuations of the surface water temperature are not too much disturbed.

2. In order to keep the surface water in good condition, the maintenance of a sufficient oxygen concentration necessary for a good stock of fish has first priority.

3. The purification costs are yet to be determined for the works necessary to remove the oxygen utilizing properties from the sewage.

4. The amount of oxygen-utilizing substances, therefore, is the primary base for the payment of a levy.

The latter principle has been further elaborated in the first enforcement decree of the law against Pollution of Surface Waters dating from December 1, 1970. By virtue of this decree, the average amount of discharged oxygen-combining matter expressed in population-equivalents will have to be determined with each discharge.

This also sounds simpler than it is in practice. It requires a good deal of simplification to make this principle applicable to practice. The way in which this was done cannot be described in detail, but can be summarized.

1. Each dwelling from which sewage is discharged, either directly or by way of a sewerage system, is assessed at 3.5 population-equivalents.

2. To the decree has been added a table that indicates for industries or groups of industries a coefficient fixing the correlation between the number of employees, the number of kilograms annually worked up or manufactured product, and the number of population-equivalents belonging to it.

3. If in the table no figure is given for the industry concerned, an analysis has to be done. This is also possible if the industry thinks the coefficients given in the table to be too unfavorable.

   The number of population-equivalents is then determined from the analysis with the formula:

   $$\text{Number of p.e.} = \frac{Q}{180}\,(COD+4.57\ N)$$

   in which

   Q = the amount of discharge in m^3 per day;
   COD = the chemical oxygen demand in mgle;
   N = the sum of the ammoniacal nitrogen and organically bound nitrogen in mgle.

4. For sewage that has been purified biologically, the number of p.e. is determined by analysis and calculated with the formula (as far as the requirements fixed in the permit are met):

   $$\text{Number of p.e.} = \frac{Q}{180}\,(2.5\ BOD_5 + 4.57\ N)$$

   in which

   BOD_5 = the 5 days biochemical oxygen demand in mgle.

   This formula was chosen to recognize as much as possible the effect of a biological treatment plant. This plant of course must then be operated according to the instructions, e.g. it will not be allowed to reduce artifically the BDO_5 of the effluent by pouring a bit of poison into it.

Who are these polluters, and how is the levy to be paid? The polluters are generally as follows, to mention the most important ones:

1. municipalities, that discharge sewage by way of sewers;

2. industries, that discharge their wastewater independently or collectively.

Both groups have to pay an annual levy. They will have to fill in a tax form and then the government will fix the amount of the levy from the table or from a calculation and look after the collection.

The execution of this system requires an inspection service that supervises the observance of the conditions of the permit and the correctness of the tax return. The advice of the Government Institute of Wastewater Treatment may be followed on these matters. Besides, correction is possible if there is reason for it.

For 1971, the level of the amount of the levy has been fixed on 2 guilders (about $0.57) per p.e. This amount is intended to increase by 2 guilders annually towards such a level as to cover a great part of the building costs of the sewage treatment plants.

A gradual rise of the levy has been chosen in order to give industries which still discharge much wastes without any treatment enough time to diminish the amount of their discharged oxygen-combining substances, by taking measures in the production process, or by building treatment plants themselves.

The effect of the principle "the polluter pays" is in the Netherlands now for the big government-managed watercourses.

The same principle, however, though elaborated in a slightly different way, has already been in practice for many years in a number of regional districts, where early anti-pollution measures had to be taken.

The projection and building of sewage treatment plants needs a great deal of skill. Good management of the plants in operation is also required. Therefore, there is in the Netherlands an urgent need of technical experts on varying levels. The management of treatment plants and the maintenance of high surface water quality involved administrative and organized efforts that cannot be underestimated.

There are a large number of organizations in the Netherlands that have long occupied themselves with the management of water, as there is no alternative for a country that must protect itself from flooding. The laws on water management have always adapted themselves to new requirements of the time in the course of centuries. This is expected to happen also now in the fight for preservation and recovery of good water quality.

Now that the population density has become so great that the self-purification powers of nature are unable to cope, technical purification measures must come to the rescue. These measures cost money, but they are necessary, permanently necessary; for otherwise we may find ourselves in a less agreeable situation, whereby organisms that have grown so rapidly in number finally perish in their own waste products, and this surely is not the intent of our efforts.

A STATISTICAL MODEL OF THE INTERDEPENDENCE OF RIVER FLOW RATE AND POLLUTION CONCENTRATIONS

By Henryk Mańczak
Director, Water Economics Research Institute
Central Water Resources Board
Warsaw, Poland

Proper control and management of water economics call for continuous monitoring of water resources, both quantitavely and qualitatively. Quantity variations within individual catchments and drainage basins have been monitored for a long time, in most countries, by means of gauging stations. The methods for interpretation of water level and discharge data are well established. Each year the results are published in form of annual hydro-meteorogical reports. Qualitative control of surface water is conducted in monitoring cross-sections by means of manual methods or fixed, floating or movable automatic water quality monitoring stations, which are integrated within a network of regional or country-wide systems of water quality control, in a manner similar to the gauging stations system.

Analyses of water samples collected in the monitoring cross-sections and operation of equipment installed at the automatic water quality monitoring stations (AWQMS) provide large quantities of data concerning both rate of flow and quality of water. Thus, each year abundant material is being collected on physico-chemical and hydro-biological water composition and stored at institutes and water pollution control laboratories, requiring efficient and feasible methods of processing(7).

The purpose of this paper is to present a method for interpretation of data from studies of pollution in surface flowing waters obtained by means of AWQMS(8). The method of processing data from monitoring cross-sections network used in Poland should also be taken into account. It results from the necessity of integrating data from AWQMS and from the monitoring cross-sections in one system.

The paper discusses basics of interpretation of results of studies obtained from Honeywell W-20 monitors, which continuously record the following quality parameters: water and air temperature, water level, pH, dissolved oxygen, oxidation-reduction potential, conductivity, chlorides and turbidity.

Remaining parameters which are included within the basic, expanded and research programs(6) should be interpreted according to the method presented in papers by Mańczak(20, 21, 22, 23)

Methods for Evaluation of Water Quality in Streams and Methods for Interpretation of AWQMS Data

First studies on water quality evaluation were based primarily on description of pollution indexes, as found from the analyses, with no respect to hydrologic phenomena(16, 17, 34, 35, 36, 37).

First relationships between concentration of pollution indexes and rate of flow were studied by Husmann(11), who had been establishing applicability of a stream in Germany for industrial purposes from the view point of CaO and NcCl content and hardness criteria. Hoak and Bramer(9) had studied the relationship of suspended solids load and flow in the Delaware river and Ohio river. Meinck(25) and Naterman(26) have found, long ago, that water quality profiles inadequately characterize the state of pollution, as they are not related to rate of flow.

Kredba, Knybel and Solc(18) have elaborated for one of the monitoring cross-sections at the Vltava river a relationship between duration of flows and concentration of pollutants, assuming that duration time of flows has a normal /Gaussian/ distribution (Fig. 1).

It follows from this figure that for the flow which lasts with higher flows for 355 days, indicative concentration of pollutants is equal to 240 mg/1.

Petru and Kredba(32) have found similar correlation for the monitoring cross-section in Chalupki on the Odra river.

Pöpel and Hunken(33) found a relationship between oxygen content and time-duration of flows in Fig. 3.

Florczyk and Mańczak(7, 21, 22) have established various relationships between pollution and flow for various parameters. According to the same method Hock(10) elaborated state of pollution in one of the monitoring stations on the Danube River. Similar studies have also been conducted by Novotny(27).

Basically three types of curves are being differentiated, presented in Fig. 2.

The shape of these curves depends on various factors, the most important being: state of river pollution, its hydrotechnical and hydrological characteristics, its self-purification capacity, distance of the cross-section from the source of pollution, characteristics of the source of pollution--particularly heterogeneity of discharged loads, its characteristics and size, etc.

In heavily polluted rivers (curve type I) in case of small distance between monitoring cross-section and source of pollution, dilution is the decisive factor in the stream. The curve is of hyperbolic character and corresponds to equation $y = \frac{a}{x+d} + b$, which in extreme conditions of $Q = 0$ intersects y axis at $\frac{a}{d} + b$, where $\frac{a}{d}$ corresponds to concentration of wastes discharged from the source of pollution. The value of b represents approximately natural pollution of the stream. Simplified equation is also used in form $y = \frac{a}{x} + b$.

In clean rivers (curve type II) the relationship under discussion could be illustrated by linear increasing function with increasing river flow, or exponential function, intersecting axis y, at $Q = 0$, at the value representing natural pollution of the river. Increase of river pollution at higher flows is due to atmospheric precipitation, and catchment run-offs, and resuspension of sludge from the river bed. Shape of the curve (type II) in case of organic pollution may be the result of self-purification processes in the reach between source of pollution and the monitoring cross-section. If the time of passage in the reach is large, then this self-purification effect will be large, as the decrease of BOD_5 in the river is primarily a function of time. At lower water levels, smaller velocities generally occur, thus time of passage is larger than at higher water levels. Moreover the coefficient of biochemical oxygen demand, k_1, is amaller than at lower initial BOD_5 values(24).

In rivers with intermediate pollution (curve type III), relationship of pollution versus rate of flow is also of intermediate character. At the low flows region the dilution is decisive, so the curve is similar to type I. At higher flows the dilution process disappears and pollutants from bottom sludges and surface run-offs become important. Thus within the flows higher than annual average the pollution increases with increasing rate of flow in the river.

The relationships discussed above could be evaluated with reference to the water temperature. However, such interpretation is possible only when handling sufficient number of observations.

If one is in possession of sufficient number of observations, this relationship should be determined with the temperature effect accounted for. For Odra River at the Chalupki (Poland) monitoring station this relationship is presented in Fig. 3.

The relationship has been constructed on the basis of 288 results of measurements in the temperature range 0.1 to 27°C. Three temperature ranges were assumed: 0 to 10°C, 10 to 15°C and 15 to 20°C. Curves are considered of being type I, the Odra river in the cross-section under consideration being heavily polluted.

An example of type II curve is the curve obtained for Olawa river, Fig. 4, in Olawa (Poland) cross-section. This river conducts rather clean waters, which supply potable water for the city of Wroclaw.

An example of curve type III is presented in Fig. 5, which shows relationship of BOD_5 versus flow in Ruhr river at Wildhausen (GFR). Author has obtained the results of studies from the Ruhrverband and the Ruhrtalsperrenverein. Influence of pollutants introduced to the Ruhr river during higher flows is in this case explicit.

Permanganate demand. Relationship of permanganate value versus rate of flow is similar to the rationship for BOD_5.

Dissolved oxygen. Relationship between dissolved oxygen content and rate of flow depends on pollution with organic compounds, on temperature, on algae and aquatic plants, and on hydraulic parameters of the river bed such as: average depth and average velocity of flow. Various curves for rivers with varying degree of pollution and having different aeration capacities are presented in Fig. 6.

Phenolic and surface active compounds. Relationship between these substances and rate of flow usually follows course of the curve having equation $y = \frac{a}{x}$, where y = phenols concentration, x = flow. Influence of temperature should be included here, as at low temperatures the process of biochemical degradation of phenols ceases completely. In heavily polluted rivers and rivers with bottom deposits, higher phenols concentrations may occur at higher flows. Surface active substances follow the equations similar to that of phenols.

Chlorides, sulphates and dissolved solids are usually characteristic of type I and II relationships.

Ammonia, organic nitrogen, nitrites and nitrates require taking into account temperature effect and as a rule follow the shape of type I curve.

Hardness and alkalinity. Relationship between these indexes and rate of flow follows type I curves.

Suspended solids. Quantity of suspended solids in stream depends not only on kind and quantity of discharged wastes, but also on the processes occurring within the stream catchment and its river bed. Denudation processes and erosion of the river bed and bottom sludge accumulation often have more evident effect on the suspended solids contents in the stream than wastewaters discharged to it. At low water levels and small velocities in the monitoring cross-section, one observes smaller quantities of suspended solids than at the higher flows. The reason is that increasing flow velocities result in denudation of still larger and larger quantities of suspended solids from the river bed and its valley and the catchment area.

The author has concluded, with Hoak and Bramer(9), that interpretation of suspended solids quantity is best performed on the basis of relationship between suspended solids load and flow on a logarithmic scale.

The results of water composition studies obtained in automatic water quality monitoring stations in German Federal Republic, are recorded on tapes(15). Recently, special equipment was constructed by Krupp for the Bundesanstalt für Gewässerkunde in Koblenz which reads from an analog strip-chart and computes in two minutes the following characteristic values of pollution indexes:

-- average daily concentration
-- sum of average daily concentrations in each month
-- average monthly concentration
-- maximum concentration and the date of its occurrance
-- minimum concentration and the date of its occurrance.

Largest experience as to the methods of interpretation and elaboration of data obtained from AWQMS has been gained by the ORSAMCO (Ohio River Valley Sanitation Commission)(2, 30). ORSANCO gets information on hydrologic phenomena from the network of hydrological service. This concerns water levels, rates and velocities of flow in individual monitoring stations, together with 3-days forecasts of these parameters. Data obtained from each water quality monitoring station, transmitted telemetrically to the ORSANCO headquarters in Cincinnati are elaborated on the IBM 1130 computer(28, 29).

Twenty-four pieces of information are obtained from each station per day. Computer processing consists of supplying the following data:

N = number of results per day
Max = maximum value
Min = minimum value
Ave = average value
σ = standard deviation

On the basis of these data, reports are being prepared for individual months in a given observation year. An example of such monthly reports from a digital computer for each AWQMS is given in Table I.

Annually published hydrochemical reports consist of general and detailed part. The general part of the annual report gives time (expressed in percent of the observation period) in which quality standards were not exceeded for some 21 chemical and bacteriological parameters, in respect to basic quality classes, i.e.:

-- potable water supply
-- industrial water supply
-- aquatic life requirements.

Moreover range of variations of the individual parameters is given in each monitoring station, as well as average monthly and average annual values. Rate of flow is presented graphically in form of average monthly flows in each year, which is compared to the flows of the preceding period. Analysis of low flows and flood stages is also conducted.

Individual pollution parameters are interpreted on the basis of so called qualigrams, quality profiles and ranges of occurrence of individual parameters along the river.

In the three-axis layout the percent of time that the daily minimum DO values were equal to or less than indicated value is plotted against DO concentration and distance. According to the ORSANCO criteria, dissolved oxygen concentration from the viewpoint of aquatic life should not fall below 5 mg/l for minimum 16 hours per day and should never fall below 3 mg/l O_2. If this value never falls below 4 mg/l O_2 the permissible conditions (3.0 to 5.0 mg/l O_2) are fulfilled. This interpretation is known in Poland as the time-duration curve of concentrations with higher concentrations.

Quality profiles are prepared for Coliform density, dissolved solids, hardness, chlorides and sulphates.

In recent years a new system of AWQMS data storage and retrieval has been developed in USA, which includes data from related fields. The system has been named STORET (Storage Retrieval)(5). The scope of the system is to distribute stored information and retrieve the data in the desired processed form according to the requirements of the interested party. STORET system includes interpretation of data to obtain loads of pollutants passing a given cross-section.

Method of Processing and Interpreting Data from Automatic Water Quality Monitoring Stations

In the elaboration of data on degree of river pollution and when using such material the need arises for precise definition of terms and for unified determination of conventional symbols and nomenclature. The nomenclature used for hydrologic elaborates can be utilized for this purpose, and should be modified, to the needs outlined above. In Poland Debski's(4) hydrologic systematics has been assumed--given in Table II, supplemented with some concepts from the field of water pollution control.

In this table symbols defining characteristic loadings are also given. The load of a waste parameter is the product of concentration and rate of flow. Load may be expressed in grams per second, kg/day or tons/year. Characteristic values are given in g/sec or kg/sec.

Indicative concentration is understood as such value of pollution parameter which has been interpolated from the relationship of concentration of a given parameter versus rate of flow, and referred to the indicative flow(20). Under the term of indicative flow in Poland we assume the value of average low flow from several years, abbreviated ALF(38).

Honeywell W-20 monitors installed at each AWQMS conduct continuous measurements and record on paper tapes, with frequency of every 2 minutes following physical-chemical parameters of water: chlorides, conductivity, turbidity, oxidation-reduction potential (ORP), dissolved oxygen (DO), reaction (pH), water temperature and water level.

Chlorides and conductivity allow for the assessment of salinity in the water. These parameters will be also helpfull in the evaluation of state of pollution resulting from inhabitants, provided natural chlorides contents of the receiver is known.

ORP potential. The value of this potential depends on the concentration of either reducing or oxidating agents. ORP measurements in surface waters lead to the evaluation of the degree of their pollution with substances of reducing properties, which with simultaneous determination of other parameters--iron being the most important--becomes a measure of the concentration of reducing organic compounds. Among the latter are aldehydes, ketones, amines and unsaturated hydrocarbons.

On the basis of numerous studies (1, 3, 12, 13, 19, 31) it has been found that ORP calculated for pH 7 is equal to 400 - 500 mvolt for clean surface waters.

It follows from 1969 all-year studies at the automatic water quality monitoring station on Odra river at Wroclaw cross-section that ORP was equal to 250 - 420 mV. This would indicate, with simultaneous low concentrations of iron, the presence of reducing organic substances.

Physical and chemical parameters of water are presented in form of daily variations graphs. From these graphs maximum, minimum and average values are evaluated for all water parameters. In case of observing significant changes in water level within a given day the flow rates will also be evaluated--corresponding to these levels--and they will be assumed for further computations. Thus obtained maximum, minimum and average values are compiled.

From the knowledge of maximum, minimum and average daily concentrations and flows--average, maximum and minimum loads are evaluated.

Data from daily reports form a basis for monthly compilation of concentrations and loads of pollution. Due to the technical difficulties each parameter is presented in a separate table.

Results from AWQMS may be also processed taking into account characteristic periods depending on rate and time of flow, water temperature and course of ice-cover phenomenon and state of water pollution. Generally, following characteristic periods are assumed:

a. Summer period including months: July, August and September when usually low water levels and low flows occur, with high temperatures and intensive oxygen utilization processes.

b. Winter period including months: January and February when ice-covers stops reaeration completely and low temperature of water does not favor self-purification.

c. Autumn period including months: October, November, December--when the river is subject to pollution from seasonally operating factories of such industries as sugar, distilleries, starch industry, etc.

d. Spring period including months: March, April, May and June when high water levels and flows are observed--favorable conditions for the river.

For impounded rivers periods connected with the methods of utilization of the water course may also be taken into account, e.g.

e. Navigation period including months: March, April, May, June, July, August, September, October and November--when river is impounded.

f. Post-navigation period including months: December, January, February when the river is not impounded and inland navigation is not going on.

The navigation period may also be subdivided into periods of spring, summer and autumn navigation.

It follows from the above that choice of characteristic periods depends on various factors and is connected with natural features of the drainage area and climate and with the hydrotechnical characteristics of the given stream.

Elaboration of data from the AWQMS for the period of year is performed on the basis of individual monthly reports from which for individual months observed highest, average and lowest values are selected.

On the basis of data contained in the annual report compilation of characteristic concentrations is made for a given year.

Frequency histograms. Characteristic concentrations presented above define extreme and average water quality in a river, giving however no evidence as to the frequency of their occurrence and their duration. Thus, they do not characterize the hydrologic and sanitary conditions of a stream and its catchment.

Frequency of occurrence of concentrations of individual quality parameters and their duration result from hydrology characteristics of the stream, rhythm of hydrologic phenomena, heterogeneity of municipal sewage and industrial wastes discharges to the stream and from the varying intensity of self-purification processes in the reach above the monitoring station. Frequency computations and time duration graphs for individual parameters allow for comparison of changes of water composition in various years and observation periods.

Frequency of these concentrations is presented in tables according to the hydrologic principles(4). Range of variations of concentrations in the period of time is sub-divided into equal compartments depending on the kind of parameters. For chlorides--for example, in case of Odra river at Chalupki, the compartments assumed were equal to 25 mg/l. Chlorides frequency curve is presented in Fig. 7.

Heterogeneity of the frequency curve indicates that water composition is not only under the influence of hydrologic phenomena but is the result of heterogeneity of wastes discharges to Odra river.

From the frequency computations one can easily construct a time-duration curve, presented in Fig. 8 which the statisticians call a summation frequency curve.

Time-duration curves of individual parameters allow for drawing conclusions concerning possibilities of water utilization on the reach below the monitoring cross-section.

In case of having turbidity and color measurements one may easily assess the number of days in the year when chemical precipitation is needed for color or turbidity removal. Moreover this relationship allows for assessment of annual cost of chemicals required for water purification, taking into account known dose of the coagulant.

If the natural water composition has been deformed by wastewater discharges located above the monitoring cross-sections, then on the basis of time-duration curve of color concentrations or turbidity one may easily assess compensation that should be paid to those located along the downstream reach of the polluted river. Similar conclusions may be drawn in case of water intakes for municipal and cooling purposes.

The knowledge of the time-duration curves for calcium and magnesium acid carbonates or calcium and magnesium sulphates and other compounds contained in water, will allow for assessment of relative costs of water softening in a given period.

From the above relationships one may also conclude whether the construction of the water softening plant is purposeful for a given industrial plant. If, for example, it follows from the curve that time duration of high hardness water within a year is only 10 days, then the softening plant is certainly not needed at all.

Time-duration curves of water temperatures may be helpful in the design of water intakes for cooling cycles in industrial plants.

Suspended solids time-duration curves should allow for deciding on expediency of construction settling taks prior to filters at water treatment plants.

Method for computing and interpretation of waste loads. Full characterization of water pollution required computations of loads of pollutants. Computations of daily loads passing a given monitoring cross-section are made as for concentrations. Finally, characteristic loads are obtained and plotted as needed.

Determination of relationship between the concentration of pollutants and flow. Determination of relationship between the rates of flow and concentrations of studied pollution parameters, i.e.: chlorides, conductivity, turbidity, ORP, dissolved oxygen and parameters from the expanded programs of AWQMS is based on statistical regression analysis. The regression curve allows, by means of extrapolation or interpolation, for evaluation of the indicative concentration on the basis of observed concentrations for a whole range of flows. Indicative concentrations obtained this way are more impartial than those calculated according to any method which takes into account only part of the observations.

Summary and Conclusions

As a result of studies conducted within fellowships abroad and time consuming research conducted in the Water Pollution Research Laboratory WERI in Wroclaw a method for processing and interpretation of data from automatic water quality monitoring stations has been elaborated. The method is based on initial processing of data from W-20 monitors and particularly on evaluation of daily values of concentrations and loads: minimum, maximum and averages, and characteristic values of concentrations and load in the period of month, year and in characteristic periods. Elaboration of data for the annual period of observation is based on establishment of characteristic concentrations and loads of individual pollution parameters and on preparation of frequency histograms, time-duration curves of these parameters and pollution loads, and curves of summary loads as well as relationship between concentration of pollution parameters and rate of flow.

Results of studies for individual years and for individual cross-sections controlled by AWQMS are published in form of hydrochemical annual reports. These annual reports contain: description of the program of studies and analytical methods, description of automatic equipment with check-up data on each sensor, general hydrologic characteristics in each AWQMS cross-section and results of interpretation of the data.

An example of the annual report prepared for the Odra river at the

Chalupki cross-section is Mańczak's paper entitled: "Degree of water pollution in the Odra river at Chalupki monitoring cross-section--in 1960"(23).

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Table I

Example of Monthly Report on Water Quality in Ohio River at Stratton Cross-Section, February 1968

Parameter	Maximum hourly value	Average maximum value	Average monthly value	Average minimum value	Minimum hourly value	% value below permissible
Dissolved oxygen mg O_2/l	15.26	13.93	11.22	7.17	7.02	100
Temperature ^oF	38.5	37.5	35.2	32.7	32.0	100
pH	6.99	6.89	6.56	6.26	6.01	100
Conductivity m /cm/25^o/	425	420	299	246	228	100
Chlorides mg Cl /l	70	70	46	19	9	100
Rate of flow ft^3/secx1000	-	160	51	13	-	100

Table II

Definition and Nomenclature of Water Levels, Rates of Flow, Concentrations and Characteristic Loads

No.	Definition	Symbols used for determining:			
		Height$^{xx/}$ of stage	Rate of flow	Concentration of pollutants mg/l	Loads of Pollutant g/sec
1.	Highest from the highests	HHH	HHF	HHC	HHL
2.	Average from the highests	AHH	AHF	AHC	AHL
3.	Lowest from the highests	LHH	LHF	LHC	LHL
4.	Highest from the averages	HAH	HAF	HAC	HAL
5.	Average from the averages	AAH	AAF	AAC	AAL
6.	Lowest from the averages	LAH	LAF	LAC	LAL
7.	Highest from the lowests	HLH	HLF	HLC	HLL
8.	Average from the lowests	ALH	ALF	ALC	ALL
9.	Lowest from the lowests	LLH	LLF	LLC	LLL
10.	Indicative	-	ALF	JS	JL
11.	Permissible	-	-	PS	PL

xx/ According to Debski's systematics the sign HHH denotes water level highest from the observed highest, while symbol HHF denotes flow rate highest from the highest. In this paper similarly, for denoting highest concentration from the highest symbol HHC is used to denote highest load symbol HHL.

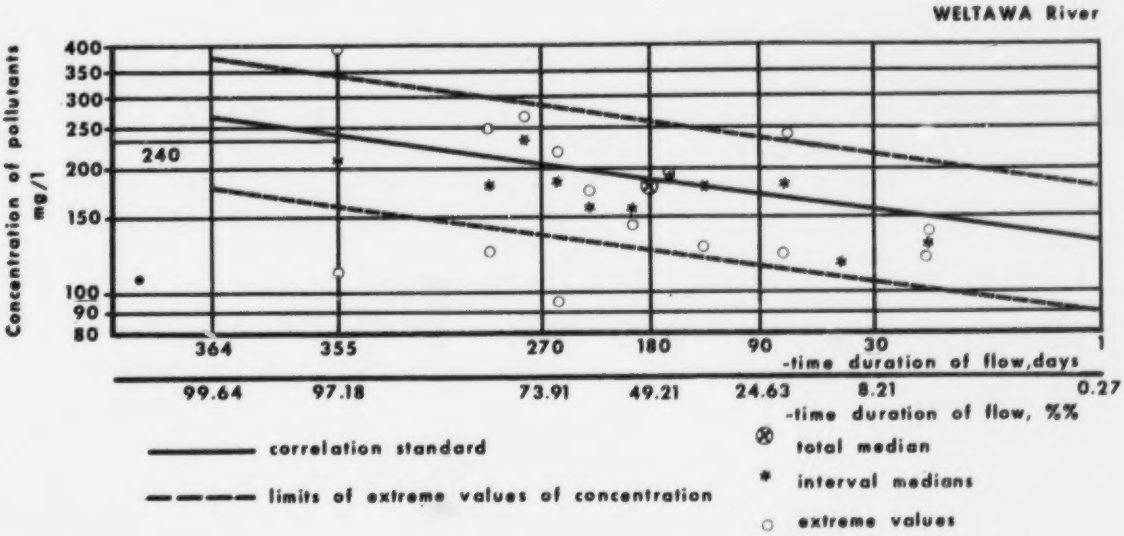

Fig. 1. Correlation between time-duration of flow and concentration of pollutants. (18).

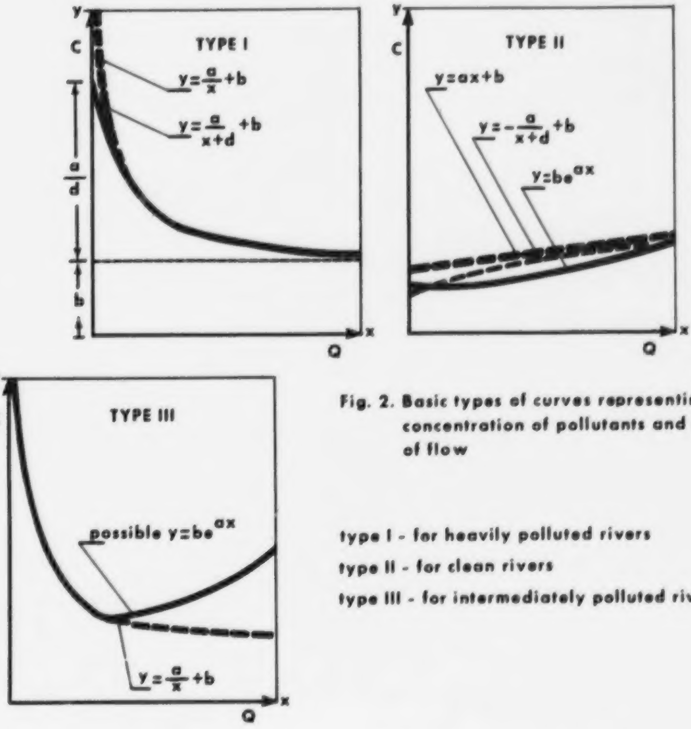
TYPE I
y
C
$y=\frac{a}{x}+b$
$y=\frac{a}{x+d}+b$
$\frac{a}{d}$
b
Q
x
TYPE II
y
C
$y=ax+b$
$y=-\frac{a}{x+d}+b$
$y=be^{ax}$
Q
x
TYPE III
y
C
possible $y=be^{ax}$
$y=\frac{a}{x}+b$
Q
x

Fig. 2. Basic types of curves representing concentration of pollutants and rate of flow

type I - for heavily polluted rivers

type II - for clean rivers

type III - for intermediately polluted rivers.

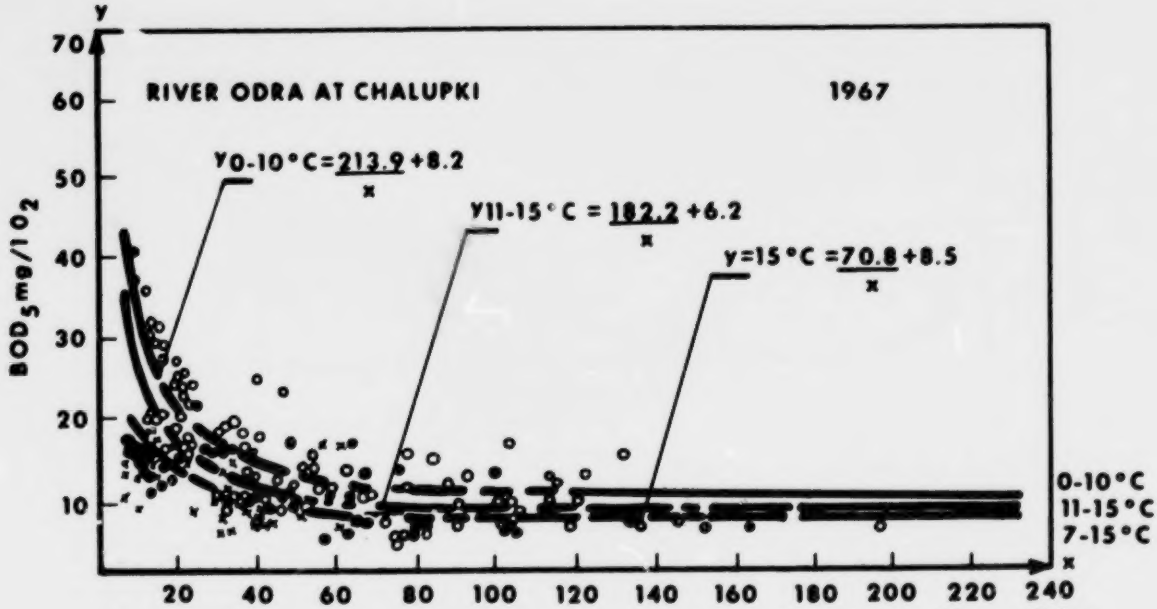

Fig. 3. Relationship between BOD5 and rate of flow in Odra rivers at Chalupki, taking into consideration the effect of temperature

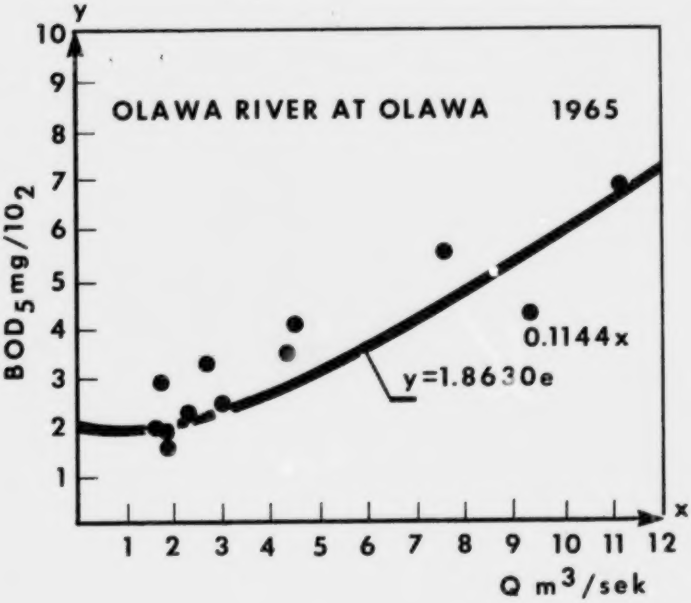

Fig. 4. Relationship between BOD_5 and flow in Olawa river, with no account for temperature

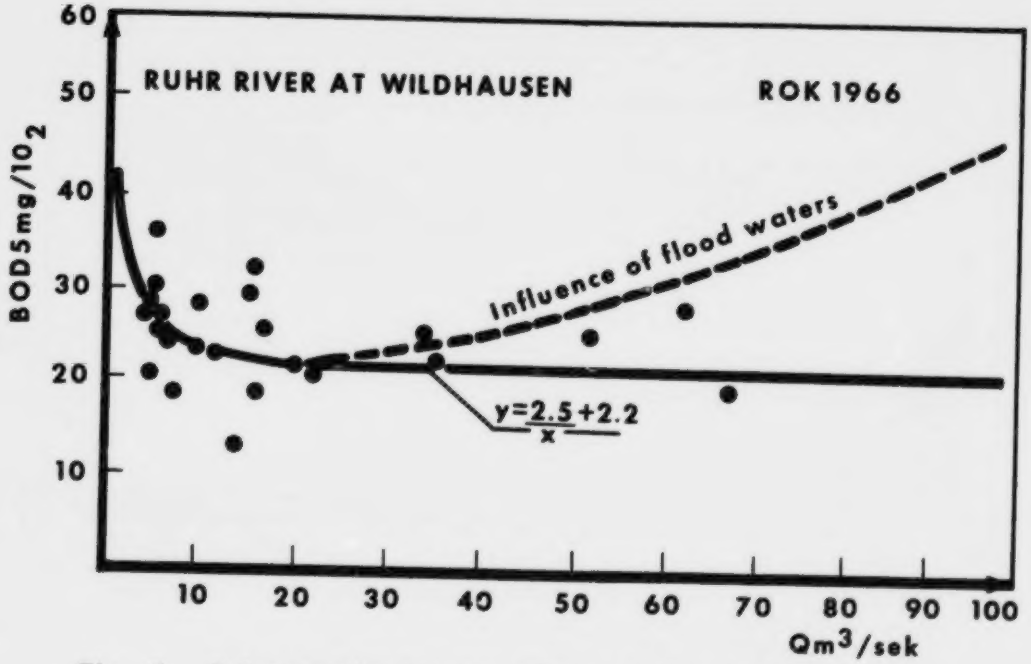

Fig. 5. Relationship between BOD_5 and Flow in Ruhr River at Wildhausen /GFR/

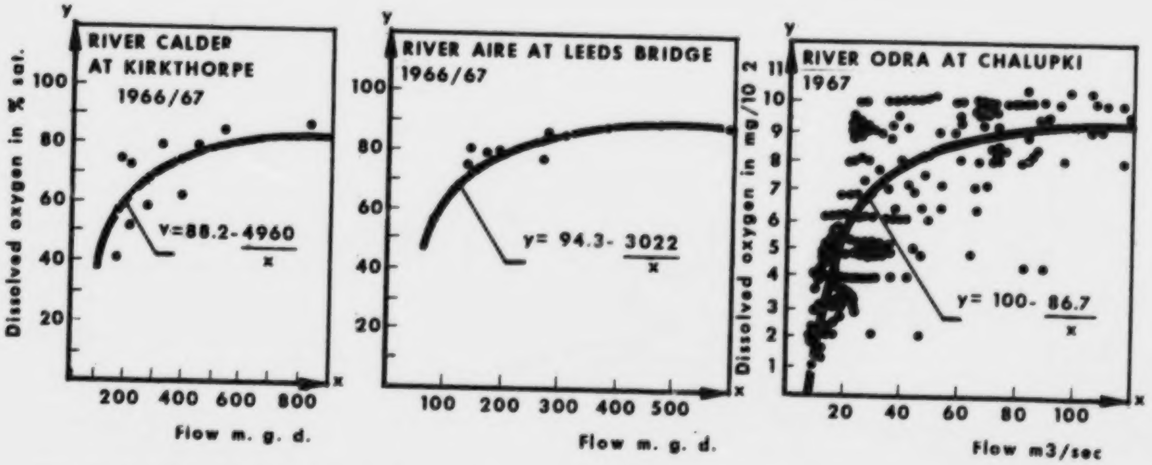

Fig. 6. Relationship between dissolved oxygen content and flow , for rivers with different capacities for reaeration: Calder and Aire (Great Britain) and Odra (Poland)

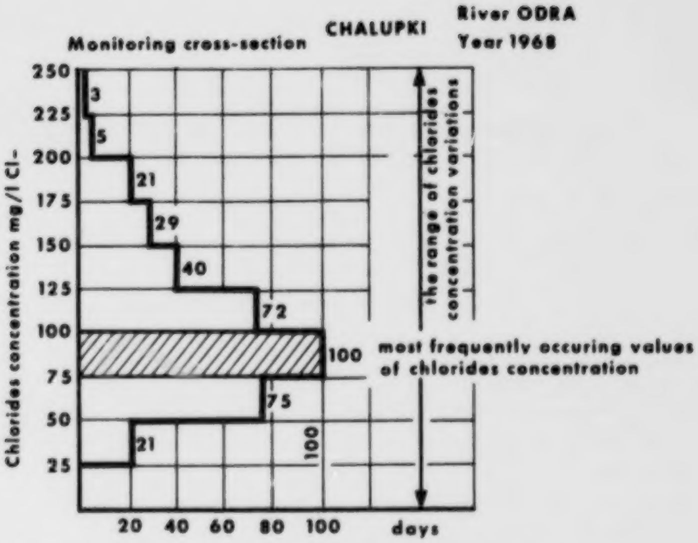

Fig. 7. Frequency of occurrence curve of chlorides concentrations in Odra river at Chalupki, 1968.

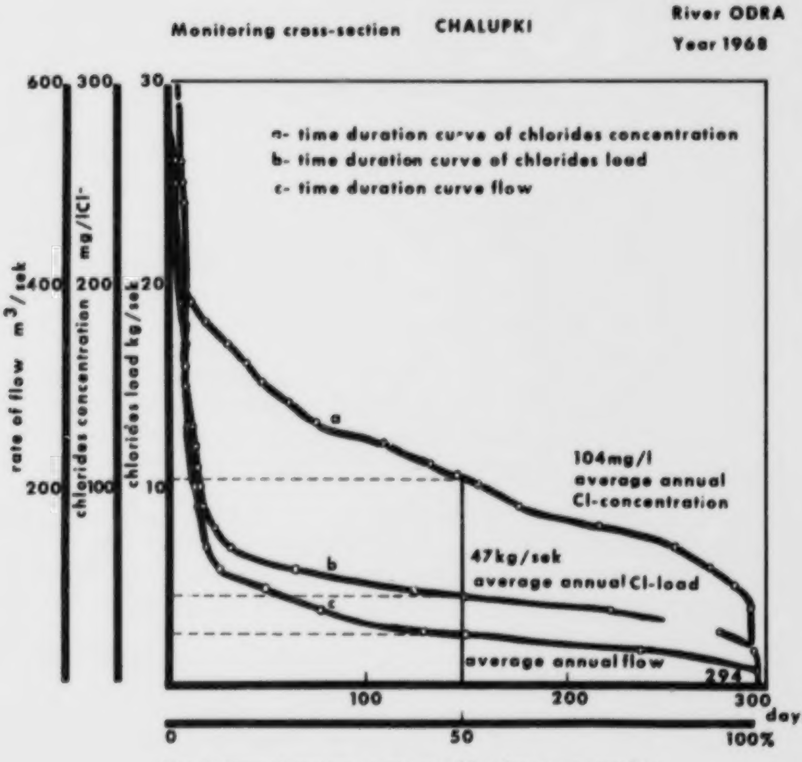

Fig. 8. Time duration curves of chlorides concentration, loads and flow in Odra river at Chalupki, 1968.

THE PREVENTION AND CONTROL OF WATER POLLUTION IN ROMANIAN SOCIALIST REPUBLIC

By eng. Mihai Lazarescu
National Council of Water
eng. George Rusu
National Council for Science
and Technology

To prevent and control water pollution is one of the steps present society is required to take and to develop, in order to limit man's endangering of his evironment through demographic and economic development. This development requires the use of increased quantities of water supplied almost entirely by surface and underground sources of fresh water, which are known to be of a limited, not very large quantity and unevenly distributed on earth.

Parallel with the decrease of available water supplies is the increased danger of ground and underground water pollution, due both to the ever-increasing quantities of wastewaters and to the complex substances they include.

Under these conditions, it is obvious that in Romania one of the most important problems of environmental protection is water pollution prevention and control. Our country, deeply committed to social and economic development, has to face particularly difficult problems in the field of water pollution prevention and control, as a result of the increased demands by agriculture, industry and population, of the increasing quantities of wastewaters discharged and of their high toxicity as well as of the spreading on the groups of larger quantities of fertilizers and pesticides.

Water pollution is also increased by a reduction in the dilution flow of the water courses as a consequence of increased use of water. In our country, both the quantitative and qualitative aspects of water resource management are considered and dealt with so as to satisfy them adequately.

A systematic concern in water quality control made it self particularly visible in the last 10 years and resulted in a series of administrative, technical and juridical measures meant to remove the causes of pollution and abate it.

As a first step, general information on actual water quality and on its causes was obtained and we got acquainted with the methods more experienced countries are using to prevent water pollution. In 1963, taking as a basis this information, special legislation was adopted to prevent further pollution.

This legislation laid the basis for co-ordinated endeavors aiming to gradually provide wastewater treatment plants and to ensure their proper operation. Steps have therefore been taken to carry out research and design work for the facilities required in wastewater treatment, to reduce quantity and toxicity of trade effluents by in-process techniques, to work out standards and standard-designs, and to use the reclaimed effluents as well as the sludge originated in these wastewaters in agriculture. Research and control institutes, training of specialized personnel and directions to coordinate water quality control within the different industrial ministries are other achievements in the same direction. Simultaneously, special legislation was adopted which established penalties in the water pollution field.

In this relatively short period since legislation was adopted, efforts were directed in carrying out both the implementation program of wastewater treatment plants and in preventing pollution by in-process techniques so as to reduce toxicity of wastewater. The efforts required a substantial contribution by the research and design institutes.

These institutes for water management work within the National Water Council but research has also been provided by laboratories working within the industrial ministries in their special fields. The institutes of hygiene, belonging to the Medical Science Academy and attached to the Health Ministry are deeply concerned in public health and environmental protection connected with water use and pollution. The Universities also develop programs of research in this direction.

Researches so far in water quality protection and wastewater treatment have had the following main objectives:

To determine the evolution of water quality of the main hydrographic basins in our country, by studying their physico-chemical, biological and bacteriological characteristics.

To study the natural phenomena of self-purification which contributes to improved polluted groundwater quality.

To establish correlations between water quality and organisms living in water; to study the sources of toxicity to fauna and flora and the limits of toxicity for certain pollutants; to establish some biological characteristics for the waters of our country; to determine the proper method of analysis for different pollutants at concentrations found in watercourses and establish their toxicity.

To work out the principles concerning mean organic wastewater discharges into watercourses, under the special conditions of our country.

The studies and research done on the main hydrographic basins in Romania have led to a knowledge of the groundwaters of our country(from the water quality point of view) to their classification (from the qualitative standpoint) to working our programs for multiple use of the hydrographic basins in Romania, as well as to developing lines of the water protection activity.

Thus, e.g. evaluation of water quality in a river course at the intake point takes into account dilution and self-purification processes and the need to satisfy properly the water user, as well. Therefore, the groundwaters, in term of users, have to correspond to one of the three quality categories for which quality characteristics were established.

Other research done or in progress is concerned with the influence chemical fertilizers, pesticides and agriculture and sylviculture have on water. The multiple use of hydrographic basins and the construction of reservoirs have required research on the eutrophication and the most efficient methods for its control.

Special consideration has been given to the protection and pollution control of Black Sea waters concerning both the discharge of industrial and domestic wastewaters from the different communities of the litoral.

Research regarding treatment of wastewaters aim at:

Supplying the necessary parameters for the design of treatment plants, by determining the flow and the physico-chemical characteristics of wastewaters, their diurnal variation in flow and composition.

Establishing the treatment techniques and the design parameters for treatment plants facilities by checking treatment processes on models, at laboratory, pilot or full scale size.

Working out instructions and standards on discharging conditions of industrial wastewaters into town sewers.

Studying a possible use for irrigation with municipal wastewaters.

Improving the construction of wastewater treatment facilities, including improvement of aeration and use of more economic and efficient media for biofilters.

Using new coagulants, extracted from industrial wastes (metallurgical slag) for water clarification, etc.

The investments involved in the last decade in abating water pollution amount to more than two thousand million lei ($100 Million), while the number of operating wastewater treatment plants increased from 400 to over 1,400.

The measures taken to construct and ensure proper operation of industrial and domestic wastewater treatment facilities are developing in parallel with measures taken to control pollution at its source. The effort to reduce wastewater quantity and toxicity resulted in reuse of coal processing effluents, reuse of rinse waters from sugar factories, recovery of useful substances from wastewater, such as fibers from pulp and paper mills, nonferrous metals from the metallo-chemical plants, oil residue from distilleries, ferrous sulphate from pickling processes of iron and steelworks, and lanolin from wool rinse waters. Wastewaters from some pulp and paper mills and fiber building board factories are recovered by extracting forage yeasts.

Some toxic reagents are replaced by less toxic ones, e.g. phenol reagents in mining processing. In oil extraction processes, underground saltwater injection has been extended as a method for wastewater discharge, while in distilleries water use is being substantiall reduced, in order to facilitate treatment.

Wastewater treatment is designed according to each specific case, taking into account technical and economic factors. Domestic and industrial waste discharges are treated combined or separate. Separate water circuits within the plants are used when technology requires this solution to increase treatment efficiency.

Important technical forces concentrate on water pollution prevention and control. This activity is coordinated by The National Water Council and carried out by local as well as its own authorities. The former are equipped with laboratories that enable them to verify and implement the measures planned, to collect and process the necessary information for coordinating and directing the general activities, as well as to provide state inspection and apply penalties when state discipline in the water field is infringed under the present legislation. If wastewater discharges cause damages to the national economy or endanger health, it is possible to order the plants that had caused the inconveniences to stop operation.

The measures undertaken have not kept pace in all sectors with the industrial and urban development of recent years. As a result on some watercourses, water quality did not meet the demands, difficulties being reported in the operation of certain users. Water pollution results in heavy damages for the national economy by requiring additional expenditure for water supply treatment, by reducing or altogether stopping production in some plants, by losses of useful substances discharged into wastewaters, by destroying fish, etc., damages evaulated to hundreds of millions a year. Alongside these direct damages are the social effects, namely the impact on the public health, decrease of the economic and social development of polluted areas, destruction of aquatic fauna and flora, etc.

Water resources being rather limited in our country, further development of production would very likely result in a deterioration of the present situation, leading to increased financial efforts and to difficulties in water use on more and more watercourses.

For these reasons the program for the construction of treatment plant facilities assigns about 350 hundred million lei ($200 Million) for the period 1971-1975, which is more than double the investments made between 1965-1970.

The planning of pollution control works in our country is based on the following principles:

For new pollution sources the investments required by the industrial or urban objectives compulsorily include the wastewater treatment at the very commissioning of the facility.

For existing pollution sources, implementation of wastewater treatment plants or improvement of those inadequately equipped are to be made gradually, taking into account the importance and the state of the receiving watercourses.

Industrial and urban development is not to deteriorate riverwater quality beyond the limits required by water use and the self-purification possibilities, whereas for degraded watercourses a reduction of pollution has to be obtained.

To establish the discharge conditions of wastewaters into river courses, the general situation of the hydrographic basin is taken into account, present users as well as those required by the national long-term plan, present as well as future wastewater discharges, dilution and self-purification phenomena, the need to ensure at least a 3rd river category, the minimum water quality on all watercourses.

Such an analysis of a drainage basin results in the water quality management plan, the tool which direct the whole activity of water quality protection in that basin.

The water pollution control program implies an increased care in correlating the industrial techniques to water quality protection requirements by adopting new technological solutions for various industrial processes and an intensified reuse of wastewaters.

Research in the field because of its complexity and its belonging to several departments requires the working out of a unique priority plan which would coordinate and direct the efforts to solve the problems, according to their economic and social importance. To this effect in March 1971 a priority research program was developed for the period 1971-1980 concerning "Water resource protection and development." With regard to the water pollution prevention and control this program recommends:

To determine the causes of water pollution and its effects on water use and public health, as well as the tolerable pollution limits.

To reduce the quantity and toxicity of industrial wastewaters by in-process techniques.

To control pollutants in the natural environment by determining the self-purification and the artificially improving parameters of groundwater quality.

To establish new wastewater treatment techniques (advanced physical-chemical treatments, new highly-efficient coagulants extracted from industrial wastes, new media for biofilters, etc.).

To improve techniques in construction of wastewater treatment facilities.

To process and remove concentrated wastewaters and the sludges resulted from wastewater treatment (improvement of digestion and dewatering methods and facilities, sludge and industrial wastes incineration, sludge and domestic refuse composting, etc.).

To recover useful substances from industrial wastewaters and reuse of reclaimed water for land irrigation.

In 1970 the "Air and water pollution control and personnel training program" was begun in collaboration with the United Nations Program for Development through the agency of the World Health Organization. As far as water pollution control is concerned, the main provisions made in the project program are the following:

Surface water quality protection (The Danube and the Arges river basin) and automated water quality monitoring.

Soil and underground water pollution control, due to infiltration from sludge, garbage and industrial waste deposits.

Working out of techniques, construction and facilities for municipal wastewater and sludge treatment.

The project provides also training of personnel by granting fellowships and technical advice by foreign consultants.

To increase the efficiency of the measures to be taken new legislation is planned which will provide an adequate framework for the development of the water pollution control program.

According to this legislation it will be strictly forbidden to put into operation new industrial plants or to extend others which would be water pollution sources because of their lacking wastewater treatment facilities or not meeting the requirements asked for by water management.

Industries discharging wastewaters are obliged to reduce to the least possible quantity their effluent, to reduce its toxicity and reuse valuable substances.

A study is in progress which will enable water management authorities to impose a tax on water use and discharge of wastewater into rivercourses or underground waters.

Considering the complexity of the problems involved in water pollution prevention and control, the measures recently taken by our State are going to provide adequate background and promises to reduce further water pollution by a constant effort of research, design, construction, operation and control, thus ensuring a rational use of water resources.

NEW PLANNING APPROACHES TO WATER POLLUTION CONTROL

By Emanuel Blitz
Head of Water Supply and Sewage Chair
Civil Engineering Institute of Bucharest

Water protection problems deriving from water requirement due to an increasing industrial development and better conditions for the growing population, involve a closer relationship between various compulsory operations.

The most important of the existing protection works have been carried out based on the collection and purification of effluents coming from local sewer systems. As compared to 1950, 1970 has brought about an increase of 4 times the initial number of the local sewer systems. The number of the treatment plants at municipal locations has also grown from 400 in 1960 to about 1400 now.

In view of the execution of these works, very large investments, stock and man-power have been mobilized, while a wide operational program, meant to provide for its implementation by keeping up with the latest achievements of progress has been worked out.

A comparison between various layout types of the last 20 years and the most recent planning schemes reveal a quite different manner of approach to the standards of projects adopted. This rapid development had to be steadily backed up by means of legal measures and a suitable management framework resulting in substantial progress, even in the occurrence of temporary or partial slowdown, whenever technical or financial resources were unavailable.

The process of planning waste systems regards them as determining elements of local and industrial development, leading to efficient environmental protection. Consequently they have to limit the operations within the water management plan to have in view the perspective layout for urban and industrial systematization, to ensure protection to surface and groundwaters, in order to keep active means for further sanitation and new water applications.

The planning has closely followed up the requirements for the development of the country taking into account financial criteria, the economy, available materials, practical and mechanical data as well as facilities, techniques and performance.

In the choice of the best scheme some of the following determining elements have to be taken into account: separate or combined sewerage, allowing urban centers to join adjacent industrial units, possible linking to nearby centers; available outlets for sewage discharge; phasing of works put gradually into service--according to stage of execution; commissioning of facilities; and cost of water canalizing.

A unique canalizing system integrating effluents as well as industrial wastes (depending on their chemical contents) is offering good results. This approach may occasionally prove more profitable to treatment plants. Sometimes however it may be related to the integral sewerage system or, eventually, to a given section of the network.

The town of Pitesti located on the Arges River, a source of water supply of the city of Bucharest, has its industrial wastes collected, after partial treatment, in the main system of Bucharest, the achievement of better effluent standards resulting from simplified waste control techniques.

The planning of a system in the Jiu Valley has required a great many variants. The best layout has brought into effect a sewerage net stretching over a 35 km wide area all along the two branches of the river. The main treatment plant is receiving an inflow of 0.880 m^3/s by way of the sewerage network. The scheme, belonging to a microzonal layout, marks an important step into the fundamentals of sewerage problems having reference to our country.

The first of these systems serves about 500,000 inhabitants of several seaside locations at the Black Sea and was carried out in 1955. Its gradual development turned into 3 large local systems. The collecting network of these stations surpasses 300 km while the discharge piping of the pumping stations reaches over 50 km.

In practice we operate on the treatment of wastewater, that is on keeping in the treatment plant those matters which could be detrimental to natural water quality. But in the actual technical conditions even wastewater treatment was not sufficient to protect certain valuable waterways.

Hence the adopted solutions in such cases are different: some of them concern water quantities, others the means to ensure a certain purification degree, and at other times it is necessary to use outlets other than those to be expecially protected.

The diminishing of the disposed water quantities constitutes one of the main approaches to river protection and as such facilitates the establishment of the methods of waste disposal.

But the realization of this goal of reducing waste quantities, applicable to industrial wastewaters, involves on the one hand the use of some "dry" technological methods and on the other hand the adoption of some water recycling or reuse schemes. Thus the disposal of industrial wastewater is influenced by the inner water supply scheme adopted in the respective industry from the four possible groups of schemes: in open circuit, with reuse in steps (or in series), with normal recycling respectively with joint circuit or with intensive recycling in closed circuit (a scheme without waste disposal into an effluent sewer).

The means to ensure the necessary degree of purification are of critical importance for the choice of the outlet and hence for the planning of the whole scheme.

Until recently satisfactory treatment was "mechanical treatment," realized most frequently by a small number of multistage cleaning tanks of Imhoff-Emscher type. An important improvement provides for biological treatment of wastewater which may involve one or several steps.

The realization of such treatment plants is based on modern equipment designed and manufactured in this country, the range of equipment for mechanical and biological treatment being relatively wide and--in any case--at an increasing development rate. There are nowadays currently designed natural and artificial mechanical-biological plants such as: the biological treatment by irrigation fields at Palas-Constanta and Eforie-Sud, the wastewater treatment by biological ponds at Focsani, biological treatment by aeration tanks with activated sludge at Pitesti, Sibiu, Cimpina, Suceava, etc.

For industrial wastewater, physical, chemical, physico-chemical and biological treatment--according to the circumstances--are used. In the near future, the use of physico-chemical treatment as a clarifying stage for urban wastewater is foreseen.

Changing points of effluent discharge to protect valuable waters is often needed. Thus wastewater from the new refinery of Pitesti is no longer discharged in the Arges River because its self-purification capacity was completely used up by the town wastewaters. As a result it was disposed into the Dimbovnic River, that flows also into the Arges River, but downstream of the water inlet for the water supply of Bucharest.

The Black Sea shore is one of the beauties and riches of our country. The width of the beaches, their exposure to sun, the suitable fineness of the sand, the saltness of the water and its temperature during the summer constitute elements classifying the Black Sea coast among the most appreciated beaches in Europe. To maintain the cleanliness of this unique resource, the wastewater is disposed of between April and October on the irrigation fields of Palas-Constanta and only during the period outside the bathing season is the wastewater disposed to sea after previous treatment.

Special protection steps are taken for certain industrial wastewater discharges by homogenization and control basin arrangements. Thus in the case of the refinery of Pitesti where treated water is received into the Dimbovnic River through a pond with a 10-day holding period, sufficient respite to control and to take steps when water isn't adequately treated for disposal.

The possibility to space at intervals the works under the conditions of putting into service the different parts as they are completed constitute a basic element in the actual concept of design.

There are used for treating urban wastewaters gravity sedimentation tanks with mechanical cleaning, biological treatment by aeration tanks with activated sludge, the aeration being made by the classical method INKA and--in the last year--with aerators with a rotor designed and produced in this country; less used are biological filters that require frequently to pumping of the whole discharge of wastewater and give difficulties in operation in cold regions and seasons.

For the digestion of the sludge retained in the treatment plants, 10-15 years ago two-story tanks were used. Now, tanks for methane fermentation are used on a large scale with a modest beginning of aerobic stabilization of sludge. The economy of digestion tank design was much improved by passing from size determination on the basis of the served inhabitants to the dimensioning on the basis of the quantity of organic matters. Devices for heating the sludge and stirring were improved too.

The dewatering of the digested sludge from urban wastewaters is achieved on drying beds, a method that--in this country--is still most advantageous. Mechanized systems of rabbling and loading dewatered sludge were introduced.

For industrial wastewater where the sludge quantities are large or the industrial process requires it, mechanical dewatering systems are used as: vacuum filters (in the pulp and paper industry), pressure filters (in the coal industry,etc.).

There is a trend to using existing basins for pretreatment of the inflow along the sewerage network. For that purposes clarification plants with mechanically cleaning facilities have been employed, allowing the sludge to pass separately, either to the pumping station, or to independent treatment facilities.

New devices meant to increase the capacity of treatment plants or to improve existing facilities are built inside the treatment plants. At any rate, the decision to abandon an existing treatment unit has to be thoroughly justified: one of the main reasons adopted in order to justify such a solution would be the needs for local extensions.

The importance of these problems is steadily growing--more manufactured goods will gradually be produced and larger quantities of water will have to be treated. More careful attention is being devoted to the determination of the main directions required to best meet the technical and economical requirements of our national economy and environmental protection in our country.

INCREASED EFFICIENCY OF WATER TREATMENT BY FLOCCULANTS

By T. Ionescu and S. Constantinescu
Ministry of Agriculture, Food Industry, Forestry and Water
Bucharest, Romania

The practice of water supply for populated centers has proved that surface water clarification by flocculants is absolutely necessary, especially in case of subsequent use of rapid filters. Flocculation is necessary also in certain types of wastewater treatment.

Experiments proved that active silica as a flocculation--aid, increases the rate of reaction, enlarges dimensions and density of flocs, and therefore improves the sedimentation and clarification of treated water. Among the flocculation accelerators there have been recently used anionic and cationic polyelectrolytes, butyl or natural polyampholytes of polysaccaride type.

The utilization of flocculants for water treatment is at present however limited because the flocculants proper and the flocculating accelerators very expensive, having a great influence on the price of water treatment. The specific flocculating reagents are produced also in limited quantities and they are used only when strictly necessary.

Starting from these considerations, first at the inorganic chemical technology department of the Polytechnic Institute Gh.Gheorghiu Dej, Bucharest, and then at the Food Research Institue, Bucharest--Baneasa, work has been done to produce flocculants with rapid and efficient clarification action, starting from raw material, accessible in rather unlimited quantities and having a very low price. Thus, a series of flocculants (T.I.) have been found, using as raw material natural and artificial silicates, metallurgical slags, used coal slags, fly ash from thermoelectric power stations, etc.

The T.I. flocculants allow a practical application of the metallurgical slags, fly ash and other useless industrial wastes.

The T.I. flocculant preparation is based on the partial leaching reaction of the above-mentioned materials by means of diluted solutions of mineral acids; such acid solutions are obtained from aluminum, iron and manganese salts, etc., and from valicylic acid (partly in solution, partly colloidal), which acts as a flocculating accelerator. The above-mentioned metallurgical slags contain SiO_2 (3.4 - 60%), Fe_2O_3 (13.7 - 45%), CaO (2 - 52%), Al, MnO, etc.

The T.I. flocculant preparation can be made under the same condition by replacing the mineral acid solutions by acid wastewaters from metal pickling facilities or by various industrial wastewaters with a mineral acid content.

The content in active compounds of the T.I. flocculants,

(a) from metallurgical slags at "Neferal" works, Bucharest,

and

(b) from fly ash at the termoelectric power plant of Craiova is as follows:

For (a): R_2O_3--22%
SiO_2--27%
For (b): R_2O_3--9.2%
SiO_2--4%

Owing to their composition (flocculant plus flocculating accelerator), the T.I. flocculants produce extensive water colloid destabilization.

The principal conditions in which flocculation is produced and the characteristics of flocs formed in surface water or wastewater treatments with T.I. flocculants are:

(a) reaction time: 2 minutes.
(b) floc dimensions: 1--3 mm.
(c) floc sedimentations time: 15--35 minutes.
(d) field of temperature for flocculation: natural temperature of water.
(e) Turbidity after flocculation(slury content):
    (1) river water--max 2--3°, SiO_2
    (2) wastewater--max 10°, SiO_2

Results Obtained by Using the T.I. Flocculants

After many experiments in treating water by means of T.I. flocculants, we can conclude that their action leads to the following performance:

(a) Physical efficiency, consisting in turbidity decrease of suspensions in raw water: 90--99%.

(b) Chemical efficiency, consisting in organic matter concentration decrease from raw water: 80--95%.

(c) Bactericidal efficiency, consisting in decrease of total bacterial number, including coliform: 75--95%.

(d) Efficiency in removing organic micro-pollutants (mono hydroxyl phenols and synthetic anion-active detergents): 50--75%.

(e) Efficiency in radioactive water decontamination, consisting in removal of radioactive isotopes: over 94%.

(f) Economical efficiency, consisting in reducing the cost of usual flocculating reagents: 1/4--1/5.

The use of T.I. flocculants decreases considerably the investments for sedimentation units, as a result of detention time shortening by 50--70%, and for biological treatment plants, taking into account the physical, chemical, bactericidal and organic micro-pollutant removal efficiencies.

Application of T.I. Flocculants

According to studies and researches made in laboratory and pilot-plants, the T.I. flocculants have been introduced at the water supply of the Podari-Craiova sugar plants on Jiu River.

The following projects have been made: wastewater treatment plant at Salonta slaughterhouse; wastewater treatment plant at IAS "30 Decembrie," Bucharest; the utilization of T.I. flocculants at the reef, pulp and paper combine, Chiscani (Braila) and at the procines complex, Caracal.

At present, researches are being made for application of T.I. flocculants at many water treatment plants for urban water supplies.

According to the circumstances, water treatment by T.I. flocculants and lime solution can achieve other effects, as:

(a) Reduction of temporary hardness of water before ion exchange treatment.

(b) Decrease of certain negative phenomena produced by saprophytic micro-organisms.

(c) Production of sludges with organic matter content, suitable for agricultural fertilizers. In case of slaughterhouse wastewater, the sludge attains a yield increase for tobacco, sugar-beet and tomatoes of 33--36%. In case of the sludge from porcine complex wastewater, the increase is approximately 30%.

(d) Production of treated water to be used for irrigation or recirculation for industrial processes.

In some cases, wastewater treatment by T.I. flocculants need not be subsequent to biological treatment. In case of wastewaters containing great quantities of organic slurries, pre-treatment by a T.I. flocculant, followed by a biological treatment is recommended to decrease the BOD_5 to accepted limits.

APPROACHES TO PREVENTION OF WATER POLLUTION

By
Mircea Negulescu, Lidia Vaicum, Vetena Ghederim
Margareta Wlezek, Alexandru Cicei, and Angela Eminovici
Deputy Director and Staff Members
Research and Engineering Institute for Water Management
Bucharest, Romania

Determination of Toxicity and Biodegradability of Some Pollutants Frequently Met in Wastewaters

Owing to industrial development, especially of chemical and petrochemical industries which are producing various goods on a large scale, many organic chemical pollutants quite different from natural organic matter have appeared in industrial and municipal wastewaters. In many cases, these pollutants are biologically nondegradable or quite toxic for microorganisms in biological treatment plants or rivers, resulting in inhibition of the biochemical treatment or of self-purification in streams.

Owing to their capability of metabolic self-regulation depending on conditions in the medium, microorganisms react against the occurrence of these pollutants by assimilation and detoxification processes. During these reactions, the cellule components can be modified, especially in the event that the final product has not become inoffensive for microorganisms.

In the same processes, certain poisonous organic substances stimulate the admission of enzymes induced into cellules or can result in genetic mutations leading to adaptation of microorganisms either in the sense of survival in the presence of the poison or of a partial assimilation. In this latter case, the poisonous substance can be transformed into a biodegradable substance.

Starting from these considerations, our research concerning the criteria in determination of toxicity and biodegradability has been centered on the idea of detecting the modifications induced in the microorganisms of activated sludge.

Toxicity Determinations

The research was conducted using activated sludge obtained in continuous-flow laboratory units and being a model of industrial treatment plants. Some biochemical characteristics of activated sludge developed on easy assimilable subtrates have been determined as have the modifications produced by contact with pollutants having a more or less important toxic action. Studies have included the proteins, the glucides, the activities of some respiratory chains, enzymes and the cellular respiration, these being correlated to some classical indicators of treatment efficiency, such as removal of COD and sludge index. The following conclusions have been drawn:

The indicators investigated are constant for the sludge supplied under the same conditions (composition of nutritive substrate, air imput, organic load on the activated sludge).

Short-period intoxication tests of activated sludge (made by acrylo-nitrile, methylene, violet, trichlorpropane) have demonstrated modifications of the studied, indicator values. Particularly sensitive have appeared proteins, microorganism respiration and dehydrasic activity. The least sensitive indicator for short-time intoxication intervals has been the COD treatment efficiency. From the quantitative point of view, modification of proteins has been the decrease of concentration; from the qualitative one--the change of proteic pattern obtained by sephades gel-filtration was followed by recording of transmission in ultraviolet of the esuated fractions. The oxygen uptake of microorganisms, and the dehydrasic activity are lowered due to intoxication.

By means of the indicators, one can follow the recuperation of activated sludge or the possibility of its acclimation to the given poison.

The study of biochemical characteristics of sludge can lead to identifying the toxic traces in wastewater subject to biological treatment, before the effects of these poisoncus substances are irreversible.

Biodegradability Determinations

In assessing biodegradability, three criteria have been used:

Microorganism respiration, determined in Warburg apparatus and in the presence of testing substrate.

Removal of this substance in the activated-sludge treatment plant, under standard operating conditions.

Ecological characteristics of treated effluent, determined by its influence on aquatic organisms higher than bacteria as daphnies fish, etc.

The degradation efficiency has been controlled either by substrate removal proper (when analytical means permit) or by percentage decrease of chemical oxygen demand.

It has been stated that among parameters in respiration namely: Velocity of respiration, hourly oxygen demand and concentration or organic matter in tested solution, there is an equation of type $y=\frac{a}{x}$, where:

y represents the microorganism velocity of respiration in the presence of test solution compared to reference sample;

x represents the ratio between oxygen uptake increment in % and COD, after allowing 24 hours to ascertain if a substance is more or less biodegradable. Moreover, between the respiration velocity of a standard activated sludge in the presence of pollutants and the treatment efficiency obtained in laboratory units there is a close relation which permits, by rapid respirometric determination, to estimate the removal of organic matter accomplished in the plant (COD %).

Respirometric methods have given very interesting results in determining the biodegradability and toxicity of many synthetic substances such as chlorinated compounds, but there are some cases in which certain special physical properties of substances have not permitted correlation between respirometric results and those obtained in activated-sludge units. One example is given by detergent biodegradability research for which respirometric methods did not yield adequate results, due to surface active properties of tested substances.

The criteria for toxicity and biodegradability cannot be generalized. Besides biochemical and classical investigations to assess treatment efficiencies, specific criteria should be introduced dependent on circumstances.

Dewatering of Sewage Sludges

The problem of sludge treatment has reached major importance within the general technology of sewage treatment. The treatment methods for sewage sludges are numerous. Dewatering has an important place. The natural dewatering processes (drying beds) tend to lesser applicability than mechanical processes (vacuum-filter, filter-press), particularly for space saving and process-duration.

The correct application of sludge dewatering processes is conditional on the knowledge of filtration characteristics of the material subject to treatment. These are the specific resistance to filtration and the coefficient of compressibility.

In order to know the filtration characteristics of sewage sludge and to promote dewatering processes, it was necessary to elaborate a unitary methodology of determination and calculation, taking into account the existence of several variants. Among the known processes, the vacuum-filtrate volume measurement at different time intervals has been chosen.

The effected researches have led to clearing up some aspects of the operating method and of the expression of filterability value. The determinations effected on different sludges of municipal and industrial sewage treatment plants in our country have permitted the following sludge classification, according to the specific resistance criterion:

Difficulty filterable sludges, having a specific resistance of 10^{12}--10^{13} cm/g; in this category one can include the raw and digested municipal sludges.

Medium filterable sludges, having a specific resistance of 10^{12} cm/g or less; in this category one can include some inorganic sludges and those resulting from feed water treatment.

Easy filterable sludges, having a specific resistance of the 10^{10} cm/g; in this category one can include the sludges resulting from mechano-chemical treatment, fibrous sludges and conditioned sludges.

In order to apply dewatering processes efficiently the difficultly filterable sludges must be previously conditioned for improving the specific resistance. Among the known conditioning processes, research has been made on thickening, elutriation, conditioning with inert materials and chemical conditioning.

Previous research yields uncertain filterability improvement by sludge thickening. Our research revealed that thickening up to 8--10% solids content improves the specific resistance of municipal digested sludges and also of some sludges resulting from mechano-chemical treatment.

The elutriation of disgested sludge is recommended for sludges of specific resistance over 1000.10^{10} cm/g. Research has shown the treatment opportunity also for sludge of smaller specific resistance, since it leads to the decrease of coagulant consumption by about 40% and an efficiency increase of vacuum filters of 50%.

Research has established a relationship for determing the elutriation ratio depending on the initial specific resistance, applicable for digested sludge under 1000.10^{10} cm/g specific resistance.

The conditioning with inert material is taken into account in special cases (to improve the coefficient of compressibility) or combined with chemical conditioning to reduce the coagulant consumption. Our research recommends the use of thermo power plant slag combined with an efficient material.

Research concerning the chemical conditioning of raw and digested sludges led to certain recommendations of methodological character concerning the coagulant dose determination under laboratory conditions, on mixture, duration, intensity, and the determination of the technical limit in conditioning.

The general equation of filtration with precipitate deposit on a porous medium and the knowledge of filtration characteristics of sewage sludges have helped to establish certain realationships which can be taken as basic for sludge dewatering plant dimensioning and for optimum operating conditions. Thus, equations have been established for determining the sludge dewatering duration in filter-press, the vaccum-filter efficiency and sludge dewatering duration on drying beds.

Certain technical criteria in the choice of dewatering method have been established:

$500\text{--}2000.10^{10}$ cm/g drying beds.
$500\text{--}100.10^{10}$ cm/g vacuum filters.
$500\text{--}50.10^{10}$ cm/g filter-presses.

These criteria, which take into account economic considerations (duration of dewatering, efficiency) offer the possibility that, depending on sludge characteristics, the proper dewatering method should be chosen.

Quantitative and Qualitative Forecase of Municipal Effluent

The preoccupation for experimental establishment of a specific pollution index for municipal wastewater has been evidenced recently by continuous research activity in most countries.

The great interest in tackling this problem must be explained by the need for realistic forecasting concerning the quantity and quality of wastewater discharged by different populated centers, i.e. the principal factors which dictate the size of treatment facilities and have a direct influence on costs.

In forecasting the quality and quantity of municipal wastewater, we must foresee the future as a dynamic system with a complex structure.

Industrial wastewaters vary in different localities leading to the use of analytical methods for forecasts concerning the quality of wastewater from populated centers.

One difficult problem to be solved is that of the reliability of forecasts. The solution of this problem cannot be obtained excepty by applying a probabilistic forecast model, which should permit expressing quantitively the degree of reliability. This way of touching on the problem creates the premise of a possible application of the modern prediction and decision theories belonging to the operational research and strategic games.

In European countries, the values established by Imhoff a few decades ago are still utilized, despite opinions which contest their applicability. Although the notions of definition and the measurement methods used to determine the solids in municipal effluents shows a satisfactory homogeneity, the experiments have not lead to results certifying the homogeneity under experimental conditions. The main disturbing factors are related to the industrial wastewater and storm water. Although less generalized, the methods generated by the idea that measured magnitudes are statistical variables are more and more frequently used. This opens a large field of application for mathematical statistical theories in organizing information, and processing and interpretation of experimental results. The results also yield important modifications of the values established by Imhoff, especially the pollution index for suspended matter.

The research has had the aim to furnish values of specific indexes to be applied in the quantity and quality forecast process of the municipal effluent, these forecasts having a greater accomplishment probability and thus satisfying the exigencies with the confidence necessary for designing the treatment plants. The experimental basis has been a residential quarter whose population amounts to 15,700 inhabitants.

The program of sampling was established before the beginning of the investigations. The experimental measurement volume was forecast depending on the main objective of the work, determination of the confidence interval of the average of each variable, measured at most with a departure ± 10%, corresponding to a threshold of sensitivity = 0.05.

The secondary objectives of the research have been to find the characteristic differences between the mean values of the variable which define the quantity and quality of wastewater depending on week days and daytimes, and also to find relationships betweeen these variables.

The processing of analytical data has made evident the principal statistical parameters for each investigated variable. Their analysis has permitted the following:

The forecast based on the necessary information volume proved to be true.

The variable averages are characteristically differentiated depending on the laboratory treatment of the sample (raw settled water, filtered water).

The graphical and analytical tests have led to accepting the distribution normality hypothesis for a great part of investigated variables.

The departures from normality shown by certain variables (suspended matter and biochemical oxygen demand) can be attributed to certain displacements due to adoption within the sampling program of a certain sample type.

The comparison of the values obtained by different experiments are converging into indicating important mutations in suspended matter structure and quantity produced per inhabitant, as compared with the Imhoff values.

The experimental results are close to results obtained in experiments made in the F.R.G. and the Low Countries.

The new values obtained for the decantable slurry led by their application in design to a more correct dimensioning of the facilities for sludge treatment, important savings being possible, estimated to be 10--15% of the total investment. It appears rational, from all standpoints, to utilize the new values of specific indexes after experimental substantiation and leading to a more adequate dimensioning of treatment facilities.

Acquirement of Forage from Excess Activated Sludge

Protein need in animal food is at present one of the great problems of the world, because of the important shortage in proteinated forages.

In order to cover the necessities of proteinated forages, researchers from everywhere try to use the organic debris (mainly wastes from the food industry) as such or as working material in acquiring forage yeast by means of selected microorganism culture.

Activated sludge, a heterogeneous culture of microorganisms with a high organic matter--can represent also proteinated forage of high quality. One hopes to resolve also the problem of removal of excess activated sludge. Activated sludge represents a microorganism culture of very complex biochemical composition, among the principal constituents being: proteins, glucides, lipids, essential amino-acids, and vitamins.

The principal problems in research into use of this proteinated forage are the following:

Determination of sludge chemical composition and conditions which can improve this composition.

Study of nutritive values and of acceptability by animals.

The experiments have been initiated by means of activated sludge developed in continuously fed laboratory units using sodium acetate.

The biochemical analyses have indicated the following composition: 40-50% proteins, involving all essential aminoacids, 14-25% glucides, 7-13% lipids, B_2, B_6, PP, B_{12} vitamins, folic acid, pantothenic acid and nucleic acids.

In comparison with forage yeast, activated sludge contains more lipids, B_6 and B_{12} vitamins, but less B_2 and PP vitamins.

Other activated sludges can have relatively modified compositions, depending on the substrate and on the operating parameters of the plant. Small organic loads of activated sludge and large detention times in treatment lead to a decrease in protein percentage.

Another problem has been the study of nutritive value and of activated sludge acceptability by chickens. For this purpose, sludge developed on sodium acetate is used because, owing to laboratory conditions, the chemical composition was constant and optimum with regard to protein concentration.

Dry activated sludge, ground and sterilized by pasterurization, was subject to bacteriological control and then given as food in 5% ratio to a 3-day chicken lot.

The results have been positive. The chicken have accepted the sludge as a fodder showing a 10% weight increase against the reference lot.

The above-mentioned data are our experiment results and they lead to the conclusion that the excess activated sludge can be successfully used as proteinated forage. The economical conditions of processing (drying, grinding, sterilization, etc.) are to be determined.

AIR POLLUTION CONTROL

AIR POLLUTION AND ITS CONTROL

By Arthur C. Stern, Professor
Department of Environmental Sciences and Engineering
University of North Carolina
Chapel Hill, N.C. U.S.A.

There is not just one air pollution problem requiring control. Rather there are five separate categories of problems--Global, Continental, National, Urban and Local (Table I)--each quite different in scale and control requirements. Their common denominator is that all are caused by emission of gaseous and particulate contaminants into the air from sources; all are dependent upon the vagaries of wind and weather for the transport of contaminants from sources to receptors; and, in all, there are one or more classes of receptors, human, animal, vegetable, material, structural, or the atmosphere itself, that are adversely affected.

Global

Our global concern is that a change in the average chemical and physical composition of the atmosphere may affect the temperature of the earth. The earth could be cooled, conceivably to the point of initiating another ice age, if atmospheric contaminants sufficiently reduce the amount of solar energy that can penetrate the earth's atmosphere. Conversely, the earth could be heated, conceivably to the point of melting presently existing polar ice, raising the sea level and inundating coastal cities, if these contaminants sufficiently reduce the amount of the earth's heat that can escape from the earth into space as infra-red radiation. The contaminants whose build-up in the atmosphere could hypothetically cause reduction of penetration of solar energy are suspended particulates, which have the ability to absorb and scatter solar energy, thereby preventing it from reaching the earth. The contaminants whose build-up in the atmosphere could hypothetically cause reduction in infra-red radiation from the earth are gases such as carbon dioxide which have the ability to absorb infra-red energy and be heated in so doing.

We know from measurement that the carbon dioxide and suspended particulate matter content of the atmosphere has been increasing for the last several decades; and that the temperature of the earth has decreased slightly over the same time period. This may be interpreted as meaning that the opposite effects hypothesized for CO_2 and particulate matter increase may be counterbalancing each other, with the hypothetical effect of particulate matter to a slight extent prevailing.

The implications these matters have with respect to air pollution control are both unclear and disturbing. They imply that a major effort to decrease the particulate matter content of the atmosphere without a simultaneous decrease in the CO_2 content of the air might tip a precarious balance in one direction, and that the same could apply to any major effort at unilateral CO_2 reduction without concurrent particulate matter reduction.

Since build-up of either particulate matter and gaseous contaminants alone is undesirable, it does not seem to be desirable to allow them both to build-up because we are unsure of what will happen if we disturb the balance between them.

Because the world's temperature is presently changing at such a slow rate, we are not now in a crisis situation where decisions have to be made and implemented rapidly. We have time to test the hypotheses from which the above noted implications ensue and, by improvement of theory and by experiment to refine our understanding of the effect of changes in atmospheric composition on global ecology. We also have time to find out how to reduce atmospheric carbon dioxide and particulate matter on a worldwide scale if it becomes imperative to do so. We certainly do not know how to do so now, either scientifically or politically. Scientifically, we are embedded in a technology that burns fossil fuel to carbon dioxide for energy and we see no clear path to a non-CO_2 producing technology. Likewise, we are a long way from a technology that will restore the particulate matter level of the atmosphere to that of a century or more ago. Finally, action to reduce the CO_2 and particulate level of the world's atmosphere must be a collaborative effort of all nations of the world; and as yet we do not have effective international political machinery to accomplish this.

The only international organizations that we can look to for help with our global problem are the United Nations and its affiliated organizations; the World Meteorological Organization and the World Health Organization. The United Nations will have this problem on the agenda of its Conference on Problems of the Human Environment in Stockholm in June 1972. Background material on this subject is already in preparation. The World Meteorological Organization has taken the initiative in coordinating a worldwide network of measuring stations which should give us better information as to long term trends of atmospheric carbon dioxide, suspended particulate matter and temperature.

Continental

The continental scale air pollution problem of greatest concern is the transport of pollution across international boundaries. The best documented example of this is the alleged transport of sulfur oxides from Great Britain and Germany to Scandanavia where it is apparently washed out of the air as "acid rain," resulting in decreased pH of water bodies and soil. An earlier example on a smaller scale was the Trail smelter in Canada, whose plume of sulfur oxides crossed the border to cause extensive crop damage in the United States.

Transport on the scale postulated by the Scandanavian scientists studying the acid rain problem involves a large number of sources in one country combining to contaminate an extensive air mass which then moves to another country. This type of problem appears to be associated partcularly with the use of tall stacks to release untreated gases from the burning of sulfur-containing fuel or the smelting of sulfur-containing ore. The Central Electricity Generating Board of the United Kingdom has made a particular effort to convince the people of the U.K. that its use of high stacks are alone a sufficient means of protecting them from high ground level sulfur oxide concentrations in the vicinity of the stack. Questions are now being raised as to whether this use of high stacks, while safeguarding those living in the U.K., merely transfers the U.K. sulfur oxide problem to other European countries. For total control of sulfur oxide emission from large sources, tall stacks need to be supplemented by either the use of low sulfur fuel or ore; the use of a system for removal of sulfur oxides from the flue gases; or both. Low-sulfur fuel is transported from country to country as a highly prized item of international trade. Plants to reduce the sulfur content of both oil and coal prior to international shipment are becoming more and more common. Likewise, the search for commercially practicable processes for sulfur oxide removal from flue gas is truly international. Among the nations having organizations known to be engaged in research and development of sulfur oxide removal processes are Czechoslovakia, Federal Republic of Germany, France, Japan, Rumania, United Kingdom and United States.

The matter of possible transport of sulfur oxides to Scandanavia from other countries is on the agenda of the Organization for Economic Cooperation and Development, of which all the countries presently involved are members. An international project to study the problem has been initiated, with the Norwegian Institute for Air Research as the lead agency.

The transport of pollution across the Canada-United States international boundary has been under almost continuous study for the past several decades by the International Joint Commission (U.S.-Canada). Several such problems have been brought under control; others maintained under international surveillance.

National

On the national scale our concern is with what's happening to the air of places we normally consider unpolluted. We usually think of air pollution as an urban problem from which we can escape by getting away from the city into the clean air of the hinterland. Unfortunately, the air of the hinterland is becoming increasingly contaminated by urban air. The non-urban air masses moving into cities to flush tem is increasingly the diluted air from the same or another city. The only control that can possibly reduce non-urban background pollution concentration is the reduction of the urban pollution that causes it.

There are also a class of pollution sources found only in non-urban areas. These include the burning of fields and agricultural wastes, crop spraying, the tilling of soil, the disposal of animal excreta and of the wastes from processing animal and vegetable products. As the world population increases, food and fibre production will increase. The only way we can prevent these kinds of pollutants from increasing in proportion is to change the practices that cause them. It was noted that diluted urban pollution forms the background level of non-urban pollution. Where there are appreciable non-urban sources, the converse situation occurs, i.e. the air advected into urban areas is diluted non-urban pollution.

At this point in our discussion, the distinction between primary and secondary pollutants becomes important. Primary pollutants are those emitted into the air from sources. Secondary pollutants are those produced in the atmosphere by chemical reaction among the primary pollutants. Many of the substances we call primary pollutants when emitted from man-made sources in urban areas, are emitted to the air from natural sources in non-urban areas. Where these primary pollutants react in an urban area, we call the resultant secondary pollutants "smog." When these same kinds of substances react in a non-urban area we call the resultant secondary reaction products "haze." The necessary ingredients for the production of haze were present long before the present levels of urban pollution existed This is attested by the fact that all over the world there are mountains and forests that in antiquity were given names such as smoky or blue because of the natural haze so frequently observed above them.

For both urban smogs and non-urban hazes to form, the primary reactants must be present in reactable quantity and proportion for a long enough time and with a sufficiency of activating solar energy. There is a limited frequency of time during which the reactants emanating from an urban area meet these criteria; and, in a non-urban situation, during which those solely of non-urban origin do. The mixing of urban and non-urban air most likely has the effect of continously making-up reactant deficiencies, and therefore of increasing the frequency of time primary reactants will be present in reactable quantity and proportion. With particular regard to the hydrocarbon-nitrogen oxide secondary reaction, one may hypothesize that mountain and forest air should be relatively rich in hydrocarbons and relatively deficient in nitrogen oxides; and that urban air should be relatively rich in nitrogen oxides but sometimes deficient in hydrocarbons. Any urban-non-urban air interchange that would enrich non-urban air with nitrogen oxides and urban air with hydrocarbons, would not only increase the frequency of occurrence of smog in cities and haze in the mountains, but also create conditions conducive to haze formation in the intervening hinterland We cannot prevent the evaporation of hydrocarbon vapors from trees and other vegetation, nor can we prevent urban-non-urban air exchange. The only things we can do in this situation is to decrease urban and non-urban man-made emissions.

Urban

The global, continental and national scales of the air pollution problem heretofore discussed have been concerned mainly with the transport and diffusion of pollution produced in urban areas. However, the urban air pollution problem can be resolved only in the context of national and international trade and commerce. Urban areas depend for their existence upon importation of fuel, energy, raw materials, food, water and manufactured goods, and on the export of goods, services and wastes. Restraints on quantity, quality and cost of any of these can affect the ability of an urban area to plan and carry out a long-term strategy to clean up its air pollution. If each urban area were to plan and carry-out such a strategy independently, conflict would soon arise among their demands on national and world resources. Some measure of national and world planning and resource allocation is therefore required.

Reduced to its simplest dimensions, a long-term strategy to reduce urban air pollution is the adoption and enforcement of limitations on emissions from each individual source within the urban area; the limitations being so chosen as to their time of application and severity as to achieve definite levels of air quality at definite future dates. During the time between now and that future date, the urban area must protect itself against the short-term occurrence of a level of pollution high enough to cause disease and death among its inhabitants.

Such short-term excursions are called "air pollution episodes" and can occur when there is cessation of the normal wind movement that ventilates a city for a period of several consecutive days. We call the simultaneous absence of both horizontal wind movement and vertical convective air movement a "stagnation." Under conditions of stagnation, pollution concentrations build-up in the air over the city. The obvious tactical resolution of this situation is to rapidly and substantially decrease emissions for a period of several days until nature restores normal urban ventilation. Such tactical resolution requires some form of meteorological forecasting to warn in advance when a stagnation will occur and a well-developed scenario as to what steps the community will take once an episode emergency has been declared.

Local

The urban and larger scales of the air pollution problem are characterized by lack of ability to identify the specific source or sources of the pollution received by any receptors. At these scales the receptor receives a mixture of pollution from so many sources that only by adding a unique tracer to the emission from a specific source can its transport to the receptor be demonstrated. The local scale of the air pollution problem is that for which the source or sources affecting a receptor can be identified without the necessity of specifically adding a tracer. Abating the identified source will abate its adverse effects on the receptor. Generally where a single source or group of sources can be traced to one specific receptor, it also can be traced to other receptors to which its effluent will be transported under different wind conditions. The most common form of local problem is where the source of a unique odor can be identified Control consists of reducing the odorous effluent to the point where it can no longer be smelled. Similarly, sources of unique particles or droplets falling in a neighborhood can be identified and abated. It can be readily demonstrated that street level carbon monoxide concentration is proportional to traffic density along the street. Immediate abatement is to decrease traffic density; long term abatement is to decrease emissions from vehicles.

Air Pollution Instrumentation

An analysis of the market for air pollution instrumentation for 1970 to 1980 was recently completed for the Air Pollution Control Office of the Environmental Protection Agency of the U. S. Government. Although it defined only the American market, the levels and trends forecast have relevance to levels and trends in other industrialized nations. The market is shown to consist of three areas: instrumentation to measure air quality level, to measure emissions from stationary sources of air pollution, and to measure emissions from automobiles. The principal findings are shown in Figure 1(1) and Table II(2). The conclusion is that most instruments presently being made measure air quality, but that by the end of the decade most instruments will be made to measure emissions from stationary sources and automobiles.

Concurrent with the above study of the instrument market, the research and development needs for air pollution instrumentation were also studied(3) The findings of this study are summarized in Table III. The implications of Table III are that unless and until the required new instruments are developed and present instruments are improved, the market potential of Figure I and Table II will not be realized.

Processes for Air Pollution Control

The poorest method of air pollution control is to first produce a gaseous effluent laden with contaminant vapors, mists or dusts and then apply a collection device to remove the contaminant from the gaseous effluent. The best method of control is to so design the process that it does not produce a contaminated effluent gas stream, i.e. to provide the desired product or service without the production of air pollution.

There are numerous examples of alternate services and products that produce less pollution than those they replace. If the service is to heat a residence, and prior practice was to provide a fuel-fired furnace, stove or fireplace, the alternatives include heating by electricity, steam or hot water from a central plant. If the service is to provide transportation, and prior practice was to use individual motor vehicles, the alternatives include electrified vehicles on rails or railless; underground, or separate rights of way, or on streets and highways. An example of an alternate product is the substitution of a gas generated by gasifying solid or liquid fuel for the burning of that solid or liquid fuel. Other types of alteration that can be made to a process are changes in raw material, process chemistry, temperature, pressure and flow.

Although a few processes are proprietary and can be obtained only from their developers, most processes are in the open literature and can be incorporated into design by any competent engineering group. However, even when this can be done, it should be recognized that certain design and construction organizations are experienced with specific processes in which other organizations are novices. The experienced organizations have had the opportunity to learn from their mistakes and, presumably, will avoid them on the project in hand. The novice organization can expect its share of mistakes, but, unfortunately, these may occur on the project in hand.

Air Pollution Control Equipment

The term "Air Pollution Control Equipment" has come to mean dust collectors for removing particulate matter from an effluent gas stream; and scrubbers, adsorbers and afterburners for removing gases and vapors from an effluent stream. This is an unfortunate use of words because, as has been indicated, these devices are only a part of the resources available to the air pollution control engineer. In the United States, there is a trade association known as the Industrial Gas Cleaning Institute (IGCI) to which the bigger manufacturers of this kind of equipment belong. The greatest number of installations of simple devices such as settling chambers and cyclone collectors are made by local tinsmiths, but the larger and more expensive installations such as electrostatic precipitators, fabric collectors, and scrubbers are usually made by IGCI members, most of whom are licencees of European manufacturers, and who, in turn, have European licencees for their own proprietary designs.

Conclusion

What stands out most significantly from even so brief a review as this, is that the air pollution problem is worldwide and that its solution will require a maximum of international collaboration and interchange of information and expertise. Certainly no one nation can by itself solve the global and continental aspects of the problem. Even when the scale of the problem diminishes to compatibility with the political boundaries and jurisdiction of one nation, we find that the search for the necessary control technology transcends such boundaries. One can comprehend the motivation of individual nations each to duplicate the efforts of others in matters of national security. However, where the security of the world's atmosphere is at stake, the scarce supply of professional air pollution control talent, research and production resources should be shared on a worldwide basis.

NOTE: Portions of this paper have been incorporated in the paper, "Air Pollution--A Worldwide Problem Requiring Worldwide Solution," the author is presenting at the Session on Air Pollution Control of the Technical Meeting, Pro Aqua-Pro Vita 71, (Noise Control--Air Pollution Control--Water Economy), June 9, 1971, Swiss Industries Fair Halls, Basle, Switzerland.

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Air Pollution Technical Information Center (APTIC)
Office of Technical Information and Publications (OTIP)
Air Pollution Control Office
Environmental Protection Agency, P.O. Box 12055
Research Triangle Park, North Carolina 27709, USA

This office has published approximately 90 paperbound publications in its AP series; approximately 68 paperbound publications in its APTD series; and others in its PB and FS series. A few of these are also available in hard cover editions. Lists of these publications and their availability may be obtained by writing to APTIC. APTIC also publishes "Air Pollution Abstracts," which abstracts the world's air pollution literature.

Air Pollution Control Association
4400 Fifth Avenue
Pittsburgh, Pennsylvania 15213, USA

This association publishes a monthly journal and other publications relevant to air pollution. From 1955 to 1971, it published "APCA Abstracts," which abstracted the world's air pollution literature.

American Industrial Hygiene Association
25711 Southfield Road
Southfield, Michigan 48075, USA

This association publishes a monthly journal and other publications relevant to air pollution.

American Public Health Association
1740 Broadway
New York, New York 10019, USA

This association publishes "Health Laboratory Science," in which journal are published the Standard Methods of Ambient Air Sampling and Analysis of the Intersociety Committee of eight American professional societies.

Academic Press, Inc.
111 Fifth Avenue
New York, New York 10003, USA

This company publishes "Air Pollution" (Edited by Arthur C. Stern) 2nd Edition--3 Volumes (1968) which is the most complete air pollution reference and text book published in the United States.

TABLE I

Categories of the Air Pollution Problems

Category	Vertical Scale	Temporal Scale
Global	The Atmosphere	Decades
Continental	The Stratosphere	Years
National	The Troposphere	Months
Urban	The Lowest Mile	Days
Local	The Height of Stacks	Hours

TABLE II

Estimate of Air Pollution Instrumentation Market Total Value 1970-1980(2)

Market	Initial Purchase	Replacement	Total
	Millions of Dollars		
Ambient level			
Agencies* Continuous Air Monitors	25	17	42
Agencies* (Non-automatic Devices)	10	6	16
Stationary Source Emissions			
Industry	168	46	214
Agencies*	12	5	17
Auto Emissions			
Agencies	47	19	66
Service Area	88	18	106
Industrial (Assembly line testing)	2	1	3
		Total	464

*Agencies = Air Pollution Control Agencies

TABLE III

Research and Development Needs for Air Pollution Instrumentation(3)

A. Instruments Exist But Need Improvement or Modification

1. Stationary Source Emission Measurement
    - (a) Portable Isokinetic Samplers
    - (b) Simple Flow Detectors
    - (c) Emission Factor Determination
2. Mobile Source Emission Measurement
    - (a) Certification Testing (Particulates)
    - (b) Simple Package for Service Stations
    - (c) Real Time Analysis of Hydrocarbon Type
    - (d) Odor Measurements
3. Ambient Air Quality Measurement
    - (a) Sensitivity of Integrating Instruments
    - (b) Selectivity of Instantaneous Instruments
    - (c) Global Pollutant Mapping
    - (d) Particulate Mass (Instantaneous)

B. Need Exists But Instruments Do Not

1. Stationary Source Emission Measurement
    - (a) Analysis at Stack Conditions
    - (b) Particulate Average Across Stack
    - (c) Integrating Flow Detectors
    - (d) Referee Methods for Emission Factor Determination
2. Mobile Source Emission Measurement
    - (a) Standard System for Inspection Testing
    - (b) Portable Package for Spot Compliance
3. Ambient Air Quality Measurement
    - (a) Simple Cumulative Collectors
    - (b) Long Path Analyzers
    - (c) Multicomponent Gas Analyzers (Instantaneous)

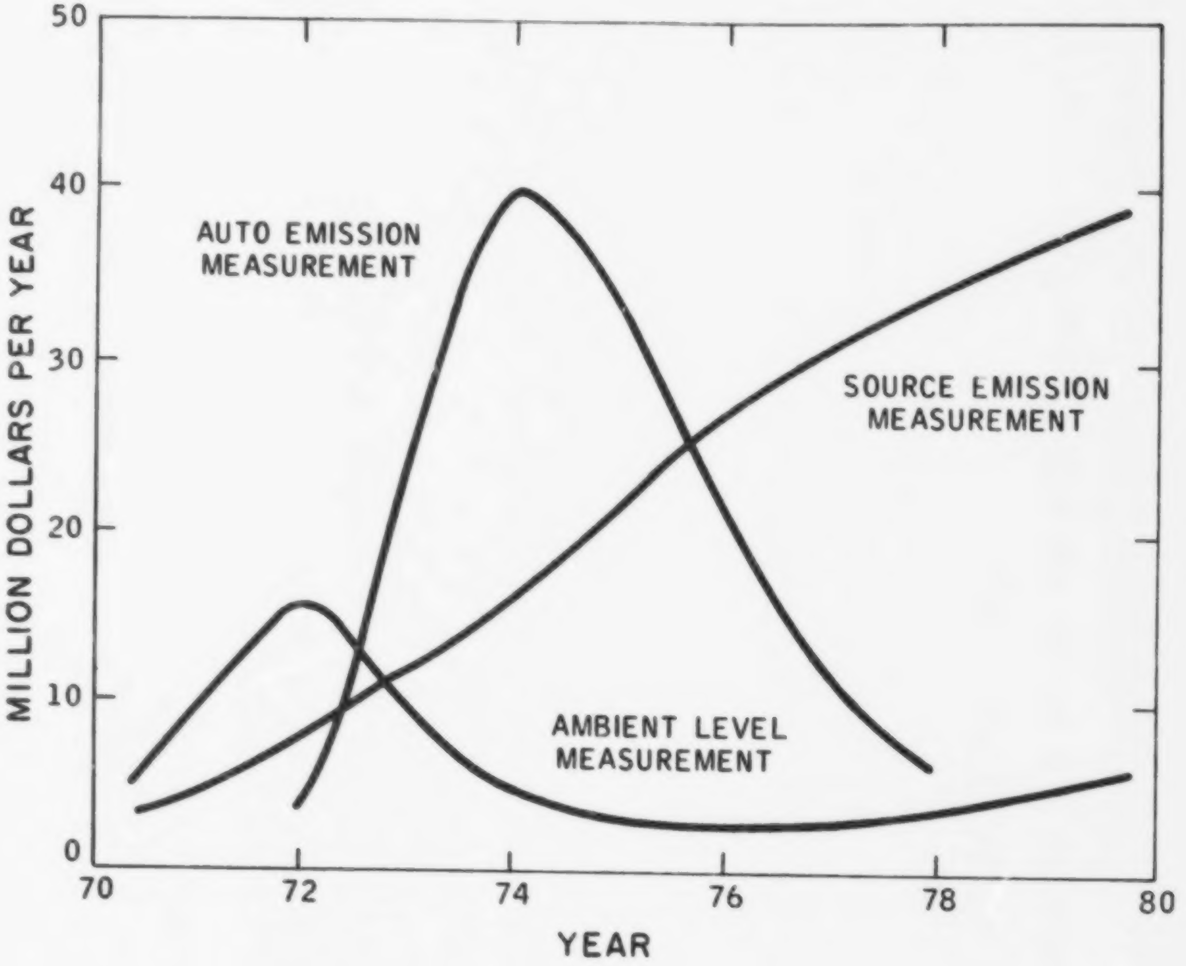

Figure 1: Time Frame for the Instrumentation Market(1)

ESTABLISHING THE EXTENT OF AIR POLLUTION CONTROL REQUIRED

By Arie Jan Haagen-Smit
Division of Biology
California Institute of Technology
Pasadena, California USA

Air pollution, one of the trademarks of our technological culture, is the result of several factors acting in concert. Emissions from natural and man-made sources provide the polluting substances. Meteorological factors such as wind and temperature inversion, together with topography prescribe the dilution volume that is available for the dispersal of these substances. In certain instances, the sun plays a part in the formation of an air pollution problem by providing the requisite energy to convert innocuous substances to materials that can damage vegetation, irritate the senses, impair visibility, and affect the health of humans and animals. The natural forces, man can do very little to modify; he can only prevent or reduce emissions resulting from his own activities.

If polluting activities could be eliminated, there would not be the air pollution problem that is being experienced worldwide. Unfortunately, many of these activities must be retained because they are essential to our comfort and well-being. There is a delicate balance between our preference to retain these activities, and our desire to protect the air environment. An essential step in maintaining this balance is a careful determination of the extent of air pollution control that is required.

Air Quality Goals

The first step in determining the extent of air pollution control required is the setting of air quality goals, which are usually stated as a series of ambient air quality standards. In California, such a standard is defined as "a specific concentration and duration of an air pollutant which reflects the relationship between the intensity and composition of pollution to undesirable effects." Recently, the United States federal government, in recognition of the differences in effects, has separated air quality standards for each air pollutant into two classes: primary and secondary standards. A primary air quality standard specifies the concentration and duration of an air pollutant which should not be exceeded as a "requisite to protect the public health," including allowance for an adequate margin of safety. A secondary ambient air quality standard should not be exceeded as a "requisite to protect the public welfare." In this sense, public welfare includes "but is not limited to, effects on soils, water, crops, vegetation, man made materials animals, wildlife, weather, visibility, and climate, damage to and deterioration of property, and hazards to transportation, as well as effects on economic values and on personal comfort and well-being."

Air quality standards, in order to be most useful in the control of air pollution, must be based on scientific information that describes conditions of exposures versus effects. The standards must not be arbitrarily established, although a safety margin may be prescribed when the basic data are incomplete or when there are uncertainties regarding the scientific findings. In practice, however, air quality standards have not always been established so ideally.

In 1959, when ambient air quality standards were first considered by California, the Health Department, and its scientific advisors discussed in depth the theory and bases for such standards The factors that were considered pertinent in setting standards were summarized in a technical report(1). These important considerations are briefly summarized as follows:

Let us consider a standard based on effects of human health. The responses of a single homogeneous population would be as represented by the response curve in Figure 1. The value X_t is the threshold or minimum concentration at which any individual in the population will feel an ill effect. The standard should be set at no higher concentration than this level.

If we were to define two separate homogeneous populations, one being more resistant than the other, our response curves would be as in Figure 2, with two separate threshold concentrations, X_{ti} and X_{tii}. However, when the two groups are combined and not distinguishable, the lower value, X_{tii} is the threshold.

In a complex population of an entire community, consisting of people with a wide range of susceptibility, the response threshold falls lower and lower as more people are observed. Even at extremely low levels there may be hypersensitive people who will feel an ill effect. The response curve of such a population would appear as in Figure 3. The threshold would be low and difficult to specify With some pollutants there may be no concentration level that affects absolutely no one. Therefore, in the real situation, zero effects do not appear to be a good basis for setting an ambient air quality standard.

One approach that could be used would be to select a concentration level as a maximum which would have no effect on a large portion of the population, say 99 percent. Such a standard based on this concentration would protect 99 percent of the population. Protection of the remaining 1 percent would be an individual responsibility involving medical care through the individuals' physicians.

Let us now consider "cost" in its broad concept in setting ambient air quality standards. Air pollution is costly in terms of damages to materials, of discomfort, ill-health or inconvenience. While damages to materials can be assessed in monetary terms, it is difficult to do likewise for the other effects. However, there will be a "cost," and the sum of these costs increases with the concentration of the pollutant.

The control of air pollution is also costly, and the cost of control generally increases with the amount of control or prevention needed. It would be logical to choose a control program where the total cost is a minimum. In Figure 4, the costs of air pollution, and control are plotted against pollutant concentration. The additive curve which shows the net cost, indicates that there is a pollutant concentration where the net cost is a minimum.

Another aspect of air pollution that should be considered in setting ambient air quality standards is that a single pollutant may have many separate effects. Figure 5 shows the complexity of the effects of such a pollutant, sulfur dioxide.

Some pollutants at concentrations generally found in the atmosphere, do not cause undesirable effects directly. Such pollutants may react in the air to form substances that irritate the senses, damage vegetation and materials. Hydrocarbons and oxides of nitrogen, for examples, participate in photochemical reactions that lead to smog manifestations of which eye irritation is one. Laboratory studies, however, indicate that the relationship between eye irritation and irradiated mixtures of hydrocarbons and oxides of nitrogen is not one which can be simply and clearly defined. Figure 6 is a graphical representation of laboratory data showing the observed eye irritation intensities versus hydrocarbon and oxides of nitrogen concentrations. The eye irritation severity zones are separated by isoresponse lines which represent the times in seconds it took the test subject to notice eye irritation after being exposed to the irradiated mixtures. The data show that a given level of eye irritation is not attributable to just one particular mixture, but that different mixtures may produce eye irritation of equal intensity.

The complex relationships between pollutant concentration and effects make selecting a basis for ambient air quality standards difficult. Difficulties notwithstanding, standards must be considered for all pollutants having either direct or indirect undesirable effects.

Data on Air Quality

The next step in establishing the extent of air pollution control required might be to determine the existing ambient concentrations of the various pollutants for which air quality standards have been set. For this, pollutant concentrations need to be measured. The information obtained is used to determine how much it will be necessary to reduce the pollutant levels, and in turn how much emission control is needed, to reach the air quality standards.

Adequate air monitoring is also costly. Each set of instruments that measures just the principal pollutants may represent an investment of thousands of dollars. This does not include the technical staff that is required to operate, maintain and calibrate the instruments. Because the concentrations measured are in the order of a few parts per million for some pollutants and a few parts per hundred million for others, the accuracy and reliability of the instruments are particularly important.

For the pollutants that must be monitored by spot sampling, there is the drawback that samples must be analyzed in the laboratory. Hence, the analytical results are not immediately available. These measurement procedures are for a long period; they yield no knowledge of how the concentrations in the atmosphere varied during the sample period. With particulate matter there is the additional factor of particle size, which is closely related to possible adverse health effects. Most of the measurement procedures currently used are based on total sample mass and gives no indication of particle sizes.

The large investment, both in terms of capital outlay and manpower, required to maintain a continuous monitoring station limits the number of locations where measurements of pollutant can be made. In order to fulfill their objective, the few stations must each be placed in strategic locations, and must produce data which represent exposure condtions prescribed in the standards.

Sources of Air Pollutant Emissions

We have set ambient air quality standards, measured the actual pollutant concentrations in the air, and we know something about how much control will be required. Now, we need to determine the sources of pollutant emissions, which of these should be controlled, what control technology can be applied to specific types of source and to what extent.

The type of information obtained in such surveys is shown in Figure 7. These data are for the South Coast Air Basin in California, which includes the large metropolitan region in the Los Angeles area. This basin covers about 8600 square miles and has a population of about 9.8 million.

If resources technology and authority for control were unlimited, air quality prescribed in the ambient air quality standards could be achieved quickly. But of course this is not the case. Therefore, it is necessary to establish control priorities, considering the largest source of the major pollutant, and those for which control technology is available and can be applied. The source inventory such as shown in Figure 7 can provide a guide for determining of such priorities.

This area, indeed all of California, uses very little coal. Therefore, the area is relatively free of sulfur dioxide and particulate matter emissions which are typical of a coal burning area and constitute the major air pollution problems of such an area. On the other hand, the frequent periods of low wind speeds and of atmospheric temperature inversions produce persistant atmospheric stagnation. These conditions coupled with a high incidence of solar radiation are ideal for atmospheric photochemical reactions. Consequently, the most serious air pollution problem is a photochemical one, produced by the action of sunlight on hydrocarbons and nitrogen oixides in the area. High oxidant concentration is one of the manifestations of photochemical air pollution, and this area experiences regularly the highest oxidant concentrations known.

Referring again to Figure 7, we note that motor vehicles are the major source of both hydrocarbons and nitrogen oxides. Therefore, to reduce oxidant levels in the South Coast Basin we must control emissions from motor vehicles. The next largest source of hydrocarbons is organic solvent usage. The next largest source of nitrogen oxides is fossil fuel power plants. If a high degree of control is needed to reach the adopted air quality standards, controlling motor vehicle emission alone is not enough. We must also consider controlling these other sources.

Another problem in the South Coast Basin is carbon monoxide. As Figure 7 shows, motor vehicles are almost the sole source of this pollutant.

Methods for Determination of the Necessary Reduction in Emissions

The simplest method of determining the degree of control needed is through "rollback" calculations. For example, consider sulfur dioxide. The basic equation for this calculation is $\frac{c - s}{c}$ x 100 = percent reduction required, where c is the maximum measured concentration, and s is the air quality standard. The ambient air quality standard (s) for sulfur dioxide in California is 0.04 parts per million, 24 hour average. The maximum atmospheric (24 hour average) concentration (c) recorded by air monitoring in the South Coast Basin was p.14 parts per million, Therefore, to avoid exceeding the standard, we need to reduce the atmospheric concentration by 0.10 parts per million, or by 70 percent. To do this we must reduce sulfur dioxide emissions from all sources by the same percentage.

This method can also be used for estimating control needed of pollutants that cause smog effects indirectly. In Figure 6, where the resulting eye irritation intensities are shown against various starting mixtures of hydrocarbon and oxides of nitrogen, the areas close to either axis are in the no-or-slight-eye irritation zone. To eliminate eye irritation, the two pollutants must be controlled to levels within this zone.

To estimate the degree of control needed for either or both of these pollutants, it is essential to know their pre-reaction concentrations on smog days and on non-smog days. In Los Angeles, typical morning concentrations for the days thusly categorized are represented by the two elliptical areas shown in Figure 8. The dotted line through these two areas approximates the ratio of the two pollutants as determined from emission estimates.

The laboratory data represented in Figure 6 and the air monitoring and emission data shown in Figure 8 could be combined into one figure for the purpose of determining the required degree of control. This is shown in Figure 9, which indicates that about a 70 percent reduction of both pollutants is required to go from "smog days" to "non-smog days."

As the approach is based on the maximum concentration, the calculated degree of control will be more than adequate for less polluted areas. "Rollback," however, has several drawbacks. First, each monitoring station records the pollutant concentration at its location. There is no assurance that the true maximum concentration is being recorded at any station, regardless of how many stations there are. Second, by this procedure we are requiring a degree of control that is more than adequate over large portions of the Basin. This may be wasteful of the resources for control which might be better spent on controlling some other pollutant. Third, we may not be able to reduce emissions from some sources by 70 percent because they are already being controlled to near the maximum degree possible.

Another method for estimating control requirement is to consider that the air over the basin has a certain dilution capacity which is limited by the height of atmospheric temperature inversion and the boundaries of the basin. This approach is the "box model"(2), illustrated in Figure 10.

The air over the basin is considered as a box of volume V. The height is h, the height of the inversion; the wind is assumed to be of constant speed v and direction. The box is oriented with one face of length L--perpendicular to the wind; the source emission rate within the box is S mass per unit time, assumed constant. The following are also assumed: (1) instantaneous perfect mixing within the box, so that pollutant concentration C mass per unit volume is uniform in the box at any time, (2) uniform and constant air pressure and temperature throughout the box, (3) reactions involving the pollutants are ignored, and (4) the wind blows only clean air into the bos at the rate of Q = hLv, and dirty air of concentration C leaves the box at the same rate Q. The differential equation of the model and its solution are as shown in Figure 10.

This model provides estimates of concentrations of pollutants that are emitted throughout an area at a known rate. The reliability of the estimates depend on the closeness the situation is to the assumptions listed. In actuality, mixing within the box is far from instantaneous and perfect; the air pressure and temperature and wind velocity and direction are not uniform throughout; and finally, most pollutants are not inert, others are produced from reactions in the atmosphere. A serious deficiency in this approach is that it provides an average concentration and misses the high values which a control program should be designed to prevent.

Rather than combining the emissions from all sources and uniformly dispersing them over the basin, a more sophisticated method would be to treat individually the effect of each source on the air quality in a given location, and sum these effects into one total. The dispersion of a plume from a point source over an area has been described by nonlinear partial differential equations$^{(2)}$. An approximate solution to these equations is known as the Gaussian dispersion model:

$$C(x,y,z) = \frac{Q}{\pi u \sigma_z \sigma_y} \exp\left\{-\frac{1}{2}\,\frac{(h-z)^2}{\sigma_z^2} + \frac{y^2}{\sigma_y^2}\right\}$$

where

C is the calculated concentration at the point x,y,z (g/m^3)
Q is the point source emission rate (g/sec)
u is the wind speed (m/sec)
o_z, o_y are the vertical and horizontal diffusion parameters (m)
x is the distance from the source in the downwind direction (m)
y is the crosswind distance from average centerline (m)
z is the height of the receptor above ground (m)
h is the effective source height above ground (m)

For application under certain assumed conditions, including ground level (z = o) and at the plume center line (y = o). The dispersion model is simplified to

$$C(x,y,o) = \frac{2Q}{u\sigma_z \quad 2\pi\,\frac{2\,x}{16}} \exp\left\{-\frac{1}{2}\left(\frac{h}{\sigma_z}\right)^2\right\}$$

The equations can be further refined by evaluating the constants, introducing the limiting parameter of the inversion height and assuming it equal to the mixing depth, applying factors to account for the relative frequencies of various wind speed, and introducing parameters to account for atmospheric stability conditions. However, when the model was applied to an actual case, the relationship between the measured and calculated concentrations was not conclusively established. This may be due to inadequate meteorological data, variations in elevation of the terrain, roughness of the terrain, inaccuracies in the model and the transport of pollutant into the area from outside.

Even with these difficulties solved, this model might suffice only for isolate point sources. It lacks provisions for considering the interactions of the numerous sources in a large area, and the effects of the photochemical reactions. If the model can be verified against actual air monitoring data, it can be a powerful tool in advanced planning to locate future residential, urban, or industrial expansions. Conversely, the model can indicate the necessity of removing existing installations from their present locations.

Control Options

Options that are available for control also have an important bearing on deciding the extent of control. These options are selected according to the type of sources, the kinds and quantities of emissions from these sources, feasibility of control, alternatives, and sometimes public pressure. Some options are exercised without first quantifying the benefits of the options. Others are aimed at achieving a calculated reduction in emissions. Within the spectrum of options, there are: a complete ban on emissions, equiproportional control, selective source control, and prevention of new sources.

A complete ban on certain activities can be enforced in some cases where there are suitable alternatives to the practice being banned. Open burning and waste disposal in inefficient incinerators, for examples, have been banned in many places. Such a ban requires that the material which had been burned be collected and disposed in another way.

Equiproportional control is practically suitable for a number of closely similar individual emitters. Having estimated the degree of reduction on the average, the degree of control if imposed on all similar sources. An example of this is the control of emissions from gasoline-powered motor vehicles, where every unit in an applicable model year is required to comply with a given set of emission standards.

Selective source control is practiced in cases having a number of diverse source types. Selective control may be taken according to area, sason and atmospheric conditions. Sources in areas where the problem is severe may be more stringently controlled than those in other areas. Regulations may be established for a specific season or for uncertain meteorological conditions. In this option, a high degree of judgment is required, but it provides the greatest opportunity for minimizing costs to society. Consideration must be given to a number of factors, which include:

(1) Source types--major, or of secondary importance; individual sources are large or small.
(2) Source locations--sources are isolated and have small environmental effect, or are located so as to have a relatively large effect.
(3) Possible seasonal source characteristics.
(4) Practical and technical feasibilities of optional control methods.
(5) Ease of imposing controls.
(6) Public acceptance of controls.

The control of photochemical air pollution in California is an example of selective source control. Photochemical air pollution, the main problem in metropolitan California, results from reactions involving hydrocarbons and nitrogen oxides. By far the major source of pollutants is the motor vehicle. Therefore, to reduce the effects of photochemical air pollution, control vehicle emissions must be curtailed. For hydrocarbons, the next largest source after motor vehicles is organic solvent usage, such as in surface coating and degreasing operations. It is practically and technically feasible to replace some highly reactive hydrocarbons in solvents with those having low reactivity in photochemical reactions. It is also easy to impose such controls, and hence regulations on solvent usage reflect this approach.

The combustion of fossil fuel for heat and power account for about half of the nitrogen oxides emissions from stationary sources. Here we have a choice between controlling a few large power plants and hundreds of thousands of home space and water heaters, and small commercial boilers. Again, because it is easier to control large power plants, stringent emission requirements are imposed on these sources. Small domestic sources, although collectively accounting for a sizable quantity of oxides of nitrogen emissions, are not controlled.

Prevention of new sources is the last control option. This option could be used in heavily polluted areas that cannot tolerate any additional sources. In the future, prevention of new sources may include changes in transportation system, population limitations and other measures that will limit additional polluting activities from entering an area in which the diluting capacity of the atmosphere is already exceeded. Power generating plants can be located away from metropolitan areas. Fossil fuel plants can be replaced by nuclear reactors.

Implementation of Controls

Control requirements, however sensibly and firmly established, produce no benefits until they are implemented. Air pollution problems cannot be mitigated by enacting a law, or by adopting rules and regulations alone. Regardless of the pressure of demand, emission reduction cannot be realized if the control technology does not exist. Even when technology is available and can be readily applied, a continuing adjustment of the program is necessary to assure that the controls are effective and adequate.

Figure 11 illustrates the fact that emission control envisioned today will not be adequate in future years. Control requirements must undergo continuous assessment, and must be tightened as new technology is developed. The figure shows the estimated nitrogen oxide emissions in the California South Coast Basin from 1940 to 1990 based on the present control program. By 1990, the miscellaneous small sources will have increased to account for more than half of the total emissions. Power plant emissions will remain about the same, although there are good possibilities that they can be decreased by control measures currently being investigated and by replacement of fossil fuel plants with nuclear ones. Motor vehicle emissions decrease markedly until about 1985, and thereafter decrease further by another small increment until 1990. After this time, despite the fact that emissions from individual vehicles will have been reduced by over 90 percent, total vehicular emissions will again increase due to the increase in the vehicle population which has steadily gone on year after year.

Summary

The factors that must be considered in the establishment of control requirements are numerous and complex. These include goals for air quality, the sources of air pollutants, control options, program implementation, and plans for the future. A control official does all this with the certain knowledge that his decisions, regardless of how carefully made, involve some uncertainties and a possibility of his objectives not being accomplished.

It should be obvious by now that the role of an air pollution control official is unending and difficult. Too often he is accused, perhaps in the same breath by the same people, both for being too lenient and therefore ineffective and neglectful of the public welfare, and for being too strict in requiring unnecessary controls therefore inconsiderate of the public welfare. His principal mission is one of protecting the health and welfare of the community as a whole. In his earnest effort to achieve his objective, he may succeed in pleasing very few people.

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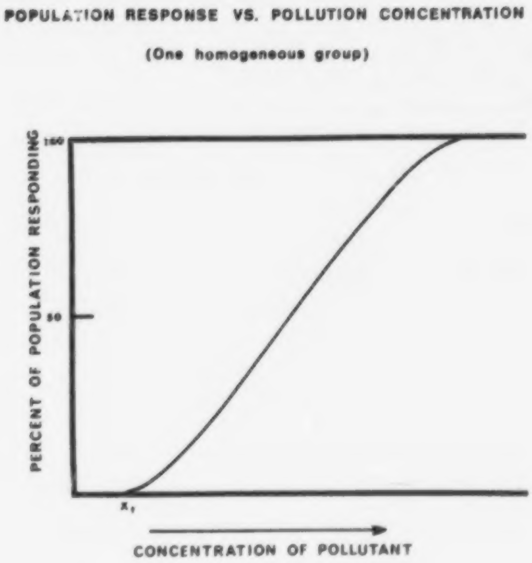


Figure 1

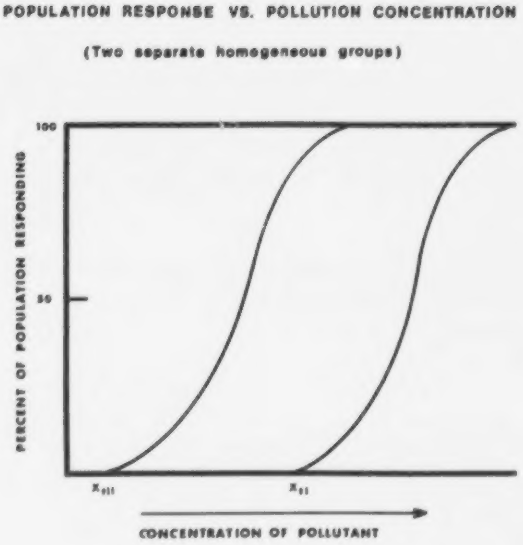


Figure 2

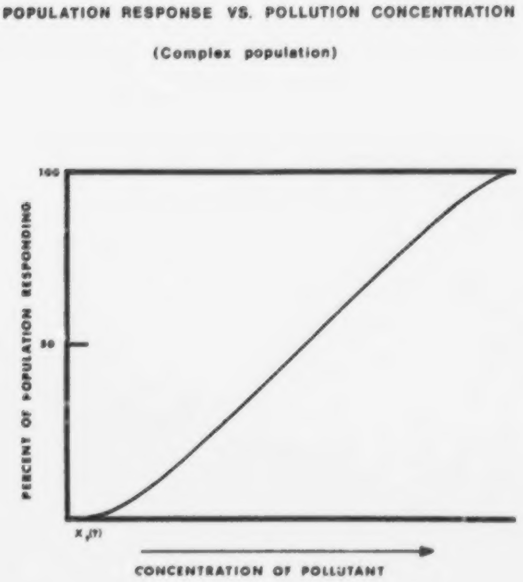


Figure 3

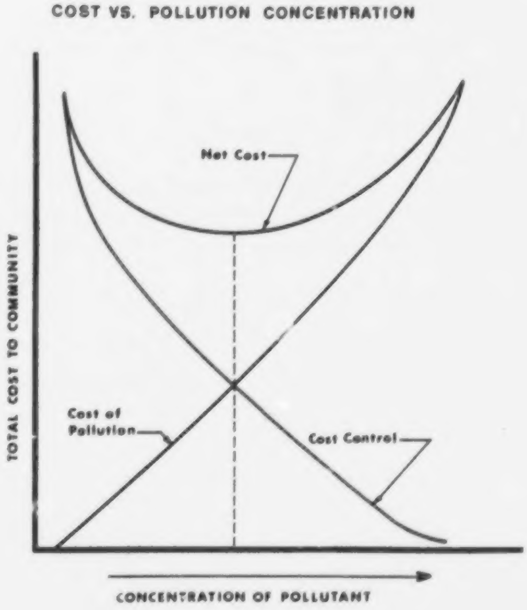


Figure 4

POPULATION RESPONSE
TO
VARIOUS EFFECTS OF SULFUR DIOXIDE

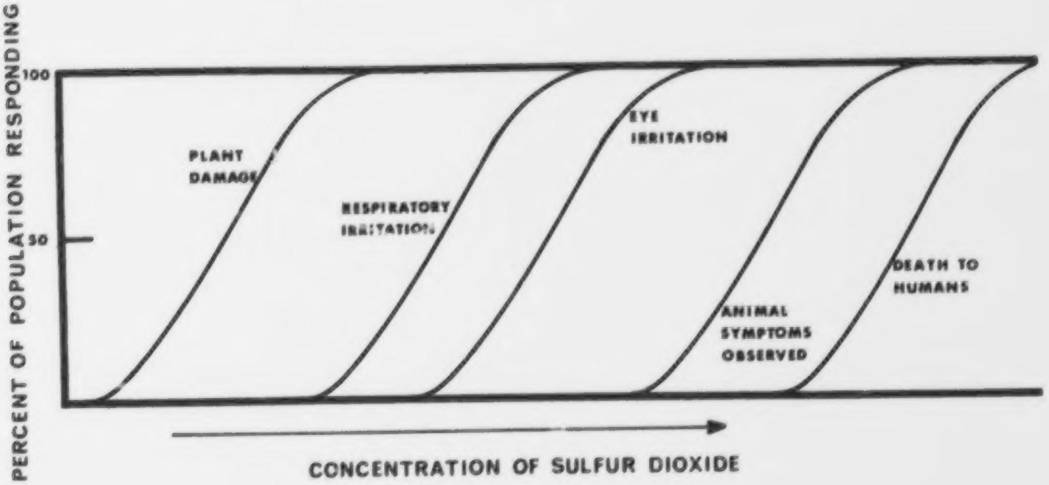


Figure 5

OBSERVED EYE IRRITATION AT DIFFERENT
OXIDES OF NITROGEN AND HYDROCARBON CONCENTRATIONS

(Laboratory Fumigation Data)

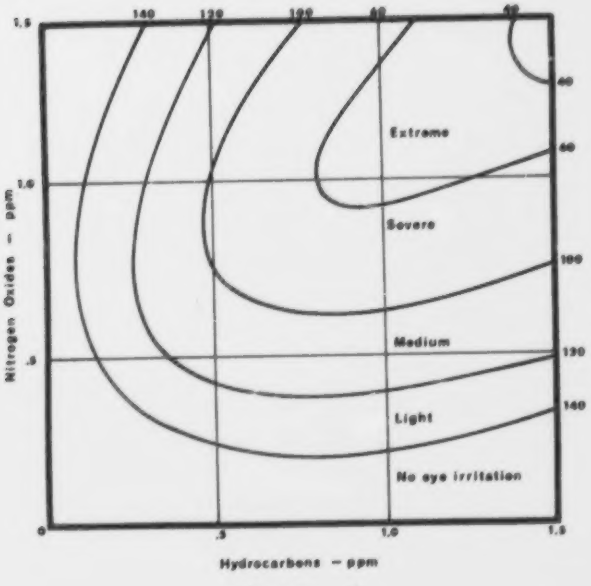
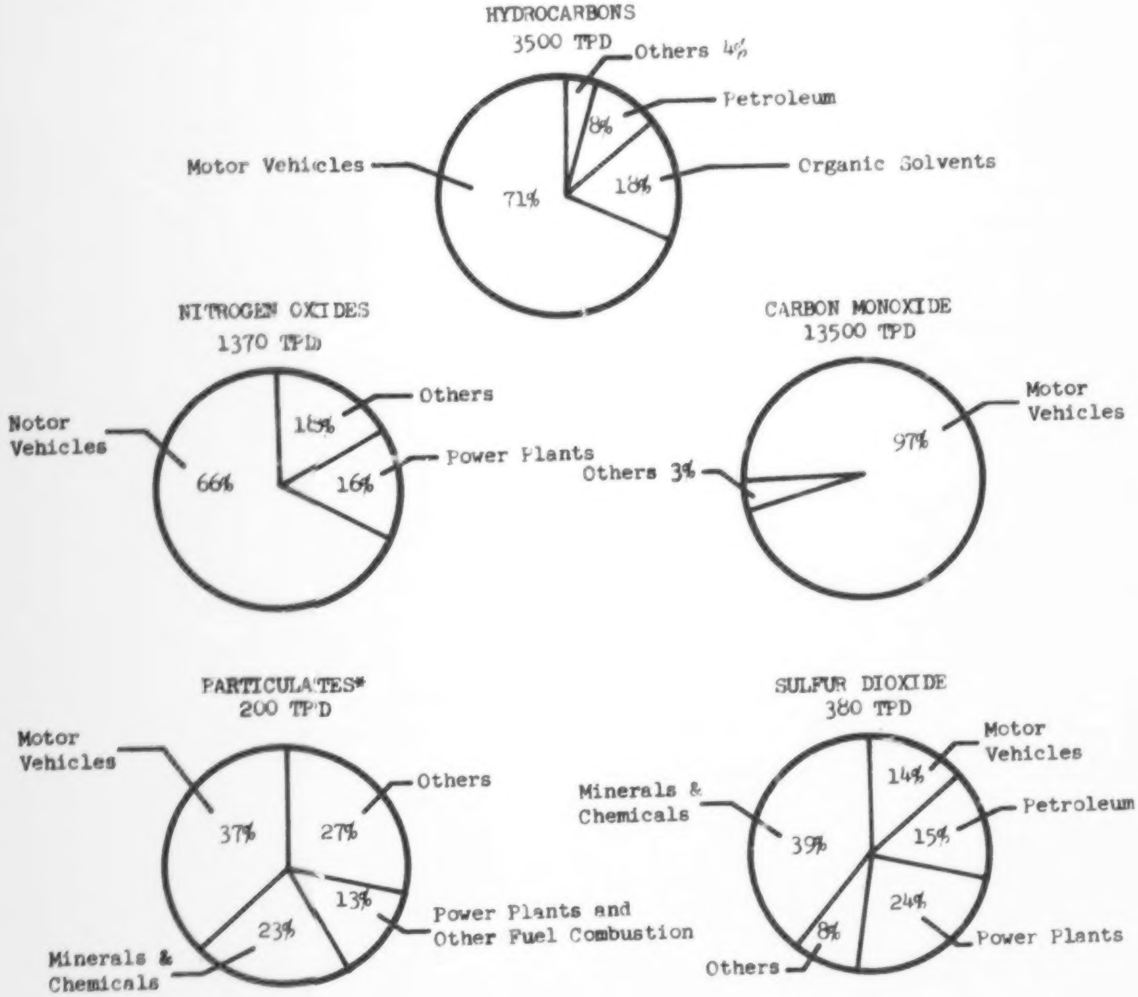


Figure 6

Percentage of Emissions
From Major Sources in South Coast Basin
1968



* Photochemical Aerosols
not Included

TPD = Tons Per Day

Figure 7

OBSERVED ATMOSPHERIC OXIDES OF NITROGEN AND HYDROCARBON CONCENTRATION LEVELS ON SMOG AND NON SMOG DAYS

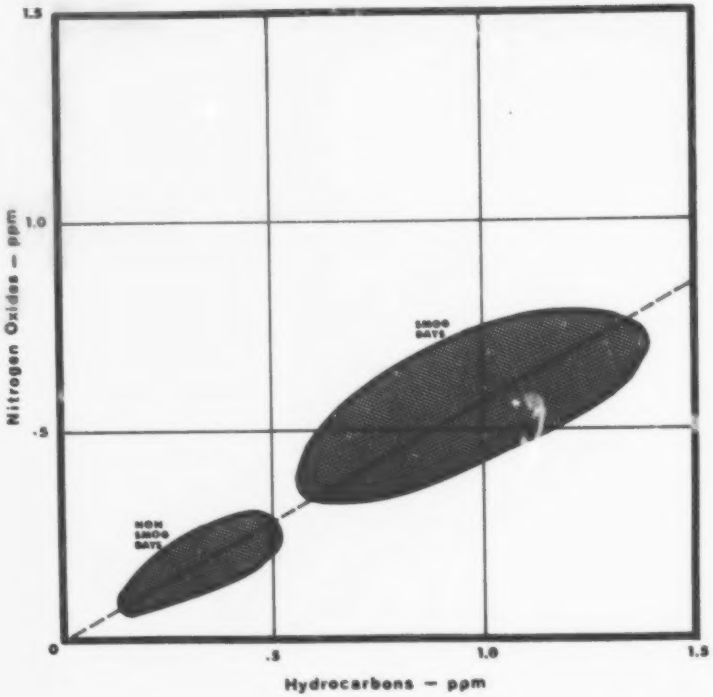


Figure 8

COMBINATION OF {FUMIGATION / MONITORING / EMISSION} DATA

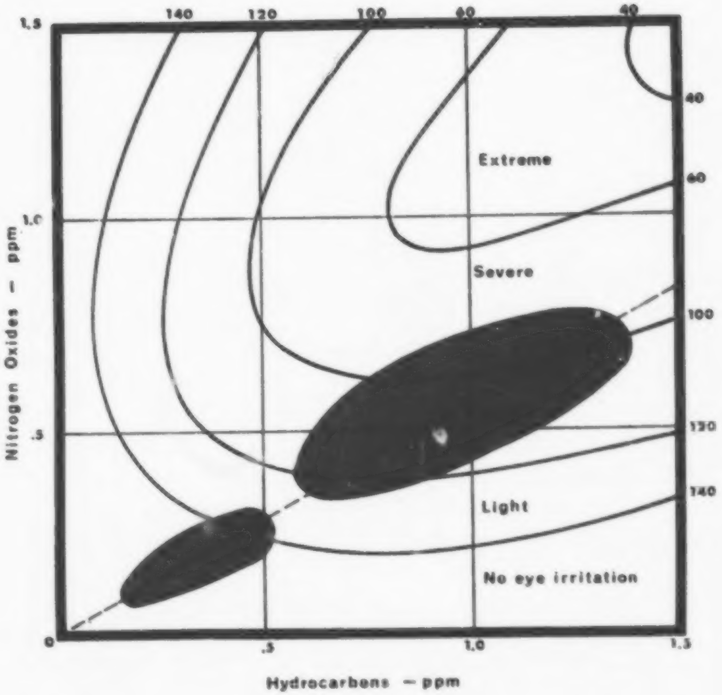
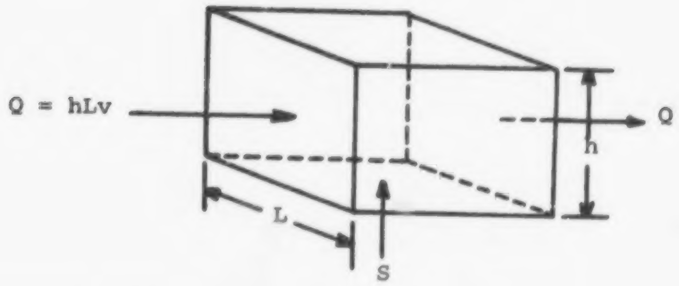


Figure 9

FIGURE 10

BOX MODEL



L = length of face perpendicular to wind
h = height of inversion
v = wind speed
Q = volumetric rate of air movement
S = source emission rate

Let C_t = concentration in box at time t
C_o = concentration in box at time t = o
T = V/Q, average residence time of pollutant

Then by mass balance, we have

$$V \frac{dc}{dt} = S - QC$$

or

$$\frac{dc}{dt} = \frac{S}{V} - \frac{C}{T}$$

The solution is

$$C_{(t)} = \frac{S}{Q} (1 - e^{-t/T}) + C_0 \, e^{-t/T}$$

As $t \gg T$, $C_{(t)}$ S/Q

Estimates of Oxides of Nitrogen Emissions
in
The South Coast Basin

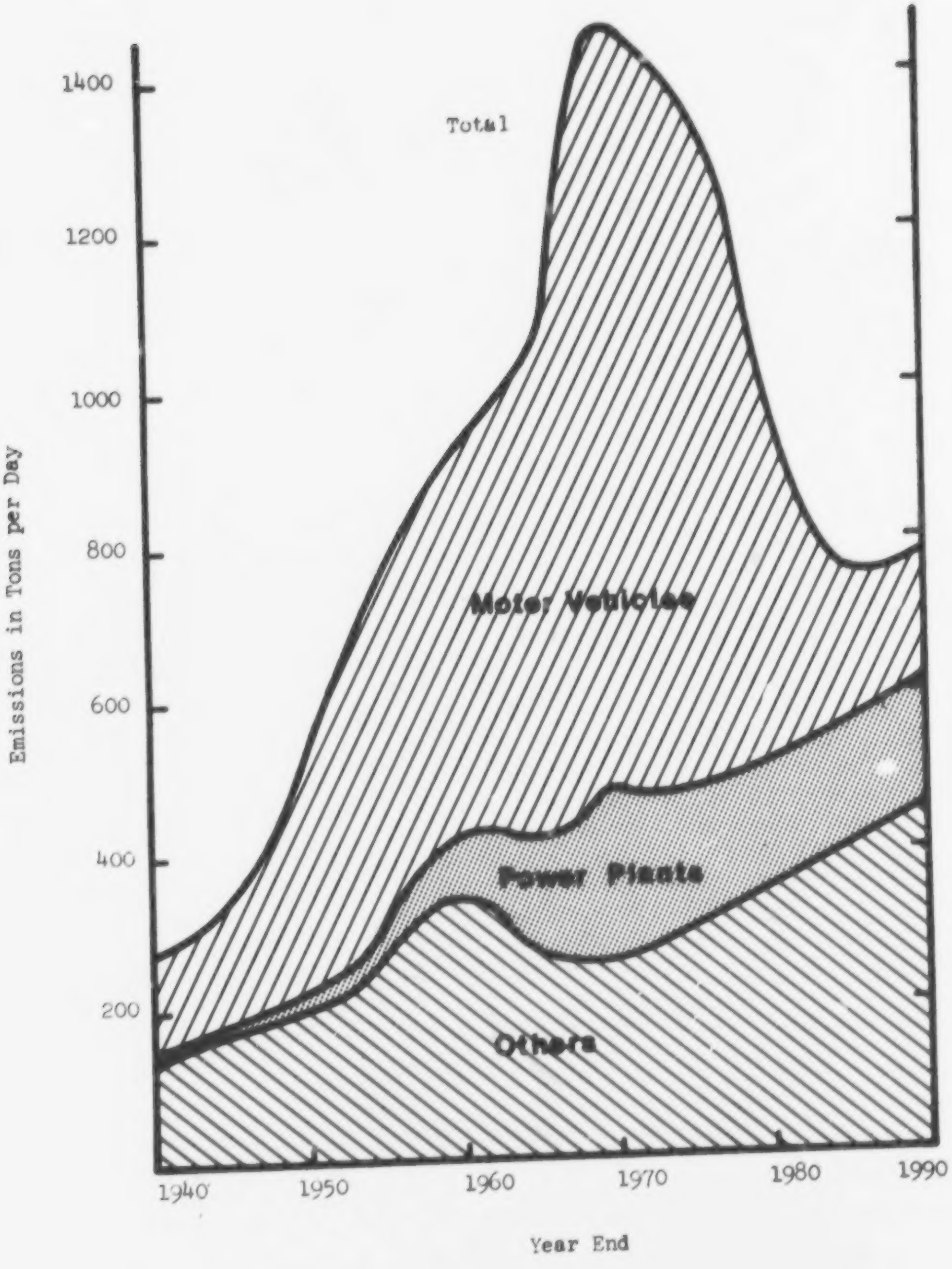


Figure 11

THE CONTROL OF AIR POLLUTION FROM COMBUSION SOURCES

By John H. Fernandes
Coordinator, Pollution Control Systems
Industrial Group
Combustion Engineering, Inc.
Windsor, Connecticut USA

"Man has applied a great deal of his energy in the past to exploring his planet, now we must make a similar commitment in order to restore that planet... The unexpected consequences of our technology often work damage to our environment, now we must turn that same technology to the work of its restoration and preservation."

President Nixon has given this challenge to the people of the United States where, as elsewhere in the world, air pollution control has increased in importance with the growth of population and industrial and commercial activity.

In the past, science and technology have been encouraged to produce goods and services, while experiencing little restraint. Now, however, the ground rules have changed. In many cases, protection of the environment, so as to maintain biological and ecological balances, has become a major design parameter.

This paper will describe various systems and equipment being marketed in the United States today which minimize pollutants emitted from combustion sources. Air pollution, as defined in this paper, is any man-made contamination of the atmosphere which harms the natural environment.

There are two major categories of air pollution: particulate matter and gaseous pollutants. A further breakdown into sub-categories can be made; however, these two general categories are sufficient to properly discuss air pollution and its control.

There are three general methods of controlling air pollutants. They are: reducing pollutant production by process modernization or modification, collecting the pollutants before they are emitted to the atmosphere, and introducing the pollutants into the atmosphere in such a manner as to properly disperse them so that no harmful concentrations can build up.

Minimizing Pollutants by the Use of Modern Systems and Processes

Where possible and practical, plant management should first consider a revamping or modernizing program to minimize offending pollutants. This should be investigated before control equipment is considered since the best solution to pollution control is not to generate pollutants in the first place. In keeping with this theme, if proper attention to detail is taken during design, most combustion processes can be operated with a minimum of pollutants generated.

Figure 1 shows a large modern steam generator. It is designed to generate 5,587,000 pounds of steam per hour. Units of this type have the most advanced fuel preparation, fuel burning, furnace, and control systems to insure a minimum of air pollution while reliably meeting steam demand.

Another means of limiting air pollution from combustion sources is the selection of nuclear power generating plants (Figure 2) in place of conventional fossil-fueled plants. This selection is basically a matter of economics. Before a final choice is made, many lengthy and complex evaluations are usually made. Of course, air pollution control equipment and systems are available for installation on fossil-fueled plants. These will be discussed later.

Normal heating and process steam can be supplied in a very efficient manner with industrial shop-assembled steam generating units. When properly designed, these units can burn a variety of fuels in a manner not offensive to the environment.

There are, in fact, 23 solid, liquid, and gaseous fuels in addition to coal, oil, and gas which can be burned in standard industrial boilers. Most of these fuels are considered wastes. Examples are refinery gas, blast furnace gas, coke over gas (gases); tars, pitch, sulfite and black liquor (liquids); and bark, bagasse, cellulose (solids). Fuel burning equipment used to fire these fuels include burners for liquid and gases, Loddby furnaces, and stokers. Some of these fuels, because of their low heating value, are burned with a supplementary fuel.

Figure 3 shows an arrangement for burning one of these waste fuels, sulfite liquor, in a standard shop-assembled boiler. In this application, a Loddby furnace is mounted in place of the regular burner.

The Loddby furnace is a cylindrical, refractory-lined unit designed to burn high-moisture content liquid wastes without or with a minimum of auxiliary fuel, depending on the heating value of the waste being burned. Capacities range from 50 to 150 million Btu per hour. In operation, the wastes are sprayed into the combustion chamber through a burner nozzle and air is admitted tangentially along the length of the furnace creating a cyclone effect. A differential pressure between the wall and the center of the furnace results in recirculation of a portion of the hot gases back to the burner area, thus completely drying the liquid wastes before they reach the wall area.

Another application of the Loddby furnace is shown in Figure 4. Materials such as phenols, cresols, tars, acrylic paints, solvents, waste oil, grease, and a variety of other liquid wastes can be burned in the unit. Besides the Loddby furnace, this system incorporates an incinerator for solid waste burning and an afterburner and spray chamber for stack effluent control.

One of the industrial processes long considered a major contributor to the pollution of our environment is paper making. Paper mills give off offensive odors and have many atmospheric discharges which have been known to carry pollutants. To reduce odor and properly clean the stack of a paper mill recovery boiler, Combustion Engineering has developed the air-contact evaporator (ACE) system (Figure 5).

The ACE system minimized odors by eliminating flue gas contact with black liquor. In the system, hot gases leaving the recovery unit economizer are cooled in a regenerative-type laminaire air heater. Incoming clean air is heated in the laminaire heater, then is routed to the cascade evaporator to concentrate the black liquor. From here, it is ducted to the furnace where it is used as combustion air.

Air pollution resulting from incineration is a major offender that comes to mind when one thinks of the combustion process. Open burning in dumps and inefficient incinerators are quite common. Because of this, there are those who will react negatively to the proposal of incineration, claiming that it is not a true solution in this environmentally conscious society, but merely a transfer of the problem to another media, such as water or air. This is a legitimate reaction. In the past, incineration has left a great deal to be desired. Open burning dumps and inefficient incinerators have built a legacy which will be difficult to live down. Equipment is available, however, to efficiently and cleanly incinerate solid wastes with only a sterile ash remaining. Figure 6 is an example of a pollution-free small incinerator. This incinerator is available in 200 to 1200 lb per hour capacities. It works on the principle of pyrolytically reducing the refuse and passing the gaseous effluent through an afterburner to control emissions.

For larger capacities, the 3-ton per hour modular unit shown in Figure 7A is available. A detail of the incinerator and scrubber is shown in Figure 7B. In this incineration system, the unprepared refuse is fed onto a reciprocating grate where it is burned in a vigorous manner to a nearly sterile ash with a minimum of putrescibles. The efficient combustion process minimizes smoke and odor. Combustion gases are routed either to a wet scrubber or to a cooling tower and electrostatic precipitator (where a steam plume my be a problem) for gas cooling and particulate matter removal before being released to the atmosphere.

The ultimate in a large and efficient waste disposal system is illustrated in Figure 8. This unit is installed at a large eastern U.S. industrial firm. The plant produces not only large quantities of solid wastes, but also industrial waste sludge. The sludge from the liquid waste clean-up process is introduced into the flash drying system which uses some of the hot gases from the furnace to dry and prepare the sludge for burning. This drying gas is then re-introduced into the furnace for deodorization.

The unit uses prepared refuse as the main fuel. The refuse is passed through a shredder and reduced in size. It is then pneumatically conveyed to the tangential burners located in the four corners of the furnace. The tangential firing method promotes rapid flash drying and ignition which insures complete and efficient combustion. The hot gases leave the furnace and pass through the various convection surfaces generating steam for use in the plant. The gases are thoroughly cleansed by an electrostactic precipitator to remove particulate matter.

Another similar system is being designed which will fire up to 20 percent refuse in a central station utility boiler. For a 125-Mw unit firing 10 percent refuse, for example, this would amount to approximately 250 tons per day of refuse. For the unit under design, the refuse will be conveyed pneumatically to the tangential firing system for suspension burning along with pulverized coal, the normal fuel.

The advantages of this system are a reduction in the cost of refuse disposal and a saving in fossil-fuel cost. Use is made of the existing burners, furnace and boiler, fans, air pollution control devices, and ash removal equipment. Additional savings are realized through the use of existing plant facilities such as laboratories, offices, security, parking, etc.

The effects of burning ten percent refuse should ve very slight, if not negligible. No significant increase in slagging or corrosion is anticipated; there may even be a minor reduction in the potential for low-temperature corrosion due to the reduced sulfur input. Comprehensive tests will determine the exact effects.

Collection of Pollutants

It is not possible to burn fuel without some pollutants being generated by the combustion process. This section of the paper will discuss the various means of collecting pollutants, beginning with the particulate matter. This category includes dust, dirt, ash, and other like pollutants Before the problem of collecting these pollutants from the plant effluent can be really appreciated, one must develop a feel for the size of particles involved. The commonly used measure of size in particulate collection is the micron. Most particulate emissions are much smaller than 44 microns (smallest practical screen size). It becomes quite clear, then, that the materials under discussion are extremely small, much less than the diameter of human hair, and they have a very low settling velocity.

These particles must be removed from the gas or they will be carried with the gas and dispersed over the countryside. Figure 9 will assist the reader in understanding the difficulty of settling this material. A ten-micron particle settles at a velocity of 18 inches per minute in a perfectly still chamber when acted upon by only gravity and viscous drag. It should be noted, however, that in most combustion processes, this ten-micron is large when compared to the average particle. The particles might be a tenth or a hundredth this size.

Mechanical Cyclone Collectors--Mechanical collectors have a long history of service. The principal representatives of this class of equipment are the familiar involute cyclones and tubular cyclones. These are devices that achieve particulate removal by means of centrifugal and gravitational forces. As shown in Figure 10, an involute cyclone collector, dust-laden gas enters tangentially thus creating a high-velocity vortex in the cylindrical portion of the device. This high-velocity, downwardly directed vortex is reversed at the bottom below the cylindrical section. The reversal is accomplished in such a manner that the separated particles are injected into a dust hopper at the bottom of the unit. The reversed gas has an axially upward component which carries the clean gas to the outlet pipe at the upper center of the unit. Since this collector, like all mechanical collectors, is primarily dependent upon differential inertia, efficiencies vary with particulate size and density, gas temperature, and pressure drop.

Figure 11 is a cutaway of a very high-efficiency, controlled-vortex, tubular mechanical separator. In this unit, the dirty gas enters axially over the dual-plane nozzles, proceeding down the cylindrical portion in a peripheral vortex where the majority of the material is transferred to the wall's boundary layer. At the reversing bowl, the axial direction of the vortex is reversed and the particulate matter is stripped to the settling chamber below. The reversed flow forms a core vortex over the deflecting bulb and proceeds axially upward to the outlet tube. This core vortex is at a smaller radius and at essentially the same velocity as the peripheral vortex, therefore, it has a greater centrifugal force. This, coupled with the regenerative skimmer at the top which directs the particles separated by the core flow to the peripheral vortex for removal, makes this an extremely efficient mechanical collector. The particulate collection efficiency for mechanical collectors is normally quite high on larger than

20-micron particles, but drops off rapidly as particles in the 10-micron range are encountered. The unit shown in Figure 11 has about the ultimate in efficiency for mechanical collectors. It maintains a high efficiency well below the 10-micron range.

Pressure requirements for mechanical collectors in normal operation are from two to five inches of water. If accurate particulate size data are available, the manufacturer's fractional efficiency curve can be used to predict collection efficiency on a given dust for this class of collector. This value of efficiency can be guaranteed now that the ASME sizing standards(1) have been accepted and are in widespread use in industry.

Scrubbers-- Scrubbers probably have the widest range of application of the various dust and mist collectors. The dust scrubbing process is extremely complex and no proven theoretical analysis of it has been derived as has been done for the other type of collectors. Many workers have investigated the configurations and methods used in scrubbing particulates from gases and certain important facts are known. First, the dust particle must impact on the water droplet to be removed, and the impaction efficiency is essentially a direct function of the relative velocity between the gas and water droplet and an inverse function of the droplet diameter(2,3). Therefore, collection efficiency is a function of the power supplied to the unit. This has been verified by Semrau(2) who found that efficiency has little relation to scrubber design or geometry, but is primarily dependent upon the properties of the dust and on the contacting power. As true as this is, a properly designed scrubber takes maximum advantage of the power supplied. The scrubbing action is a turbulent, friction-simulating type of action and can easily cover up losses. With proper allowance for the requirements of a high relative velocity and the impaction of the particles and droplets, a maximum collection efficiency can be gained for a given amount of energy expended.

Figure 12 shows two types of scrubbers. One is the high-velocity cyclonic spray scrubber where the dust laden gases are introduced into the cyclonic cylindrical section at high velocity and are impinged with a spray from a central manifold. The circulating gas rises through this curtain of water, losing its particulate matter to the water droplets which are slung to the wall and recirculated. The gas proceeds to the neck of the unit where a mist eliminator and anti-spin vanes are installed to dry the clean gas and exhaust them from the system.

In the packed scrubber, contact between the gas and the water is achieved by passing the dirty gas through a bed of material with water sprays entering the packed bed from the top. The gas forces its way through the bed of wet material towards the clean gas exit at the top.

The venturi scrubbers illustrated in Figure 13 are examples of very high efficiency scrubbers. A high velocity gas stream is formed at the throat of the venturi where the water is introduced. This breaks the water into very fine droplets for efficient scrubbing. These units would be followed by some form of droplet collector and mist eliminator to complete the gas cleaning cycle.

There are many other types of scrubbers. The ones illustrated here, however, are typical and show the basic scrubber operating principles.

Experience has shown that scrubbers can effectively remove dust from gas streams. The wet scrubber also has the ability to remove some of the gaseous pollutants (SO_x, NO_x, etc.) from the effluent if the scrubbing liquid is chemically adjusted to do this. The energy requirements can exceed six inches of water for acceptable collection of pulverized coal fly ash. In the past, this pressure drop has compared unfavorabley to the much lower values for electrostatic precipitators used on many boilers.

Electrostatic Precipitators--The electrostatic precipitator has been used for over 50 years and has built an enviable reputation. In general, the electrostatic precipitator is one of the most efficient collection devices in use today. It operates on a seemingly simple principle, although by no means as well understood as might be expected from its simplicity and long history of use in industry. In the process, the dust particles in a gas stream are electrostatically charged by a high-voltage corona discharge and are then passed through an electrical field where they are attracted to a grounded collecting surface (Figure 14). The performance of precipitators, however, is affected by complex relationships with a large number of interrelated parameters.

A review of some of the controlling features of the precipitator indicates that the gas must flow through the unit at low velocity, thereby requiring a fairly large device. One of the significant factors influencing collection efficiency is the strength of the electric field. A voltage from 50,000 to 100,000 volts is required. Other factors which effect dust migration to the collecting plates include dust resistivity, gas temperature, sulfur and moisture content of the gas, percentage of design flow, flow distribution, and carbon content of the fly ash.

Once the charged particles have been deposited on the collecting plates, several processes may be used to remove them to the hopper. These include washing, vibrating, and rapping. The dislodged particles are agglomerated into lumps of dust and readily settle into the collection hopper.

Precipitators can be designed for nearly any efficiency and they can operate over a broad spectrum of particulate concentrations. The precipitator requires a minimum draft loss of only about 1/2 to 1 inch of water and, if operating properly, has the potential of collection over 99 percent of the dust emitted from a combustion process. Sub-micron size particles can be collected with nearly the same facility as 100-micron particles. Thus, the precipitator can effectively remove entrained particulate matter to any degree desired and the purchaser can match size and cost of the unit to control requirements.

Figure 15 is an illustration of a commonly used electrostatic precipitator. The gases enter through the screen on the left, proceed between the plates which are arranged vertically, and exit out the right side. Spaced between the plates are the charged wires. The plates are rapped to remove the particles which fall into hoppers below.

Filterhouses--The filterhouse is one of the original cleaning devices. The gas to be filtered passes through fabric filters which are usually arranged in a tubular form. The accumulated filter cake on the fabric filter removes the particulate matter from the gas stream. Various methods are used to clean the filter, such as mechanical shaking, reverse jet blowing, bag collapse, and reverse flow backwash. Filter efficiencies approach 100 percent, but the overall pressure drop may be as high as 5 to 7 inches of water.

Referring to Figure 16, the dust laden gas enters at the lower left, passes through the filter giving up the dust, and the clean air proceeds to the stack. This particular fabric filter uses the air blast nozzle type of cleaning. The air nozzles at the top are sequenced to blow air which is dispersed over a jet deflector and causes the bag to vibrate and lose the collected particulate matter which falls to the hopper and screw conveyor at the bottom. In other types of bag cleaning, such as back flow, there is a temporary cessation of flow in the compartment and the air is reversed through the fabric, causing the vilter cake to be released and dropped to the hopper below for removal.

Cloth filtration has the ability to remove 99.9 percent of the particulate matter insuring practically complete elimination of plume capacity, thus making it a very desirable air pollution control system. The filterhouse has not been considered for application on combustion processes because the cost of the initial filterhouse and bag replacements have been prohibitive. Newer bag materials with longer guaranteed life at higher temperature may eventually open the way to boiler applications.

Gaseous Pollutants--Even after exhaust gases are completely cleaned of particulate matter, they may still contain offensive gaseous pollutants. These pollutants include SO_2, SO_3, and No_x. There are a number of systems under development in the United States for the removal of sulfur oxides from stack gas emissions. The principal methods being explored are dry and wet absorption, wet and dry adsorption, and catalytic oxidation. In this discussion, only the most advanced systems will be covered.

A fairly obvious solution to the reduction of SO_2 and SO_3 emitted from combustion processes is the use of sulfur-free fuel. The fuel suppliers, however, have not found economical methods of removing sulfur compounds from oil and coal. They have been much more successful in "sweetening" natural gas. Where it is possible to burn this clean fuel, the SO_2 problem is eliminated. With oil and coal, the economics justify a thorough review of the methods of collecting pollutants after combustion rather than their removal from the fuel before combustion.

Also, there are process modifications which can be explored to further reduce emissions of harmful gases. Various researchers(4) have found that low excess air and low flame temperatures reduce the amount of sulfur dioxide and oxides of nitrogen formed. This can be considered a partial solution to control of these pollutants. In addition, tests(5) have indicated that the introduction of inexpensive additives into the furnace with the fuel can reduce the formation of sulfur oxides.

At the present time, the Tennessee Valley Authority, as part of the U.S. Air Pollution Control Office's program to demonstrate the feasibility and cost of processes for reducting sulfur oxide emissions, is conducting a $3 million, 18-month test at their 150,000-kilowatt Shawnee generating unit. Powdered limestone is being injected into the combustion chamber where it combines with the gaseous SO_2 and SO_3 to form solid particulates which can be removed by the unit's electrostatic precipitator along with the fly ash. Tests done by Combustion Engineering indicate that it is possible to remove 20 to 30 percent of the sulfur oxides in this manner.

Another program similar to this one was conducted by C-E Air Preheater a subsidiary of Combustion Engineering, in conjunction with the U.S. Department of Health, Education and Welfare. In these tests, an alkaline earth material was fed into the gas stream ahead of a filterhouse. The fly ash and alkaline earth material collect on the fabric filter. The sulfur oxides in the gas, in passing through the filter cake of alkaline material, react with this material, thereby removing SO_2 and SO_3 from the gas stream. Results have not been published, but it was possible to remove a meaningful percentage of the SO_2 and SO_3 from the gas stream if the filter is operated above the equilibrium temperature which is just over 600 F. Unfortunately, the success of this particular program must await the development of fabric filters that can successfully operate at temperatures in excess of the 600 F.

Alkalized Alumina Process (Bureau of Mines)--This process(6,7) removes sulfur dioxide from flue gas by dry absorption at 625 F. Alkalized alumina pellets, flowing countercurrent to the gas, are used as the absorbing agent. The spent absorbent is regenerated by reduction at 1200 F with hydrogen or reformed natural gas, yielding H_2S which is converted to element sulfur in a Claus furnace.

Work reported to date has been done using a small furnace burning one to four pounds per hour of pulverized coal and a pilot plant burning 165 lb of coal per hour. Present estimates indicate capital costs of $10 per kilowatt and net operating cost of 70¢ to $1.50 per ton of coal. The operating costs include overhead charges and a credit for sulfur of $20 per ton. A number of engineering problems associated with the development of inexpensive absorbent preparation methods and reducing gases need to be resolved.

Catalytic Oxidation Process-- This process(7-9) involves high-temperature flue gas cleaning to prevent catalyst fouling, catalytic oxidation of SO_2 to SO_3 at 950 F, and cooling of the SO_3 rich flue gas to just above the dew point in an economizer followed by an air preheater. The gas then enters a packed tower and shell and tube heat exchanger where the condensation of the sulfuric acid takes place. There, a stream of cool sulfuric acid contacts the gas lowering its temperature to 225 F. Further cooling to 110 F follows. A Brink mist elininator removes the remaining entrained sulfuric acid mist. On-stream washing of the mist eliminator removes fly ash build-up.

The manufacturer reports that a total pressure drop of 41.5 inches of water is needed to accomplish 90 percent removal of SO_2 while recovering an acid with a concentration up to 80 percent.

The operating costs are based on the sale of 70 percent sulfuric acid. This could involve a considerable marketing problem, depending on the plant location. Appreciable quantities of diluted H_2SO_4 are used in fertilizer manufacture, but transportation cost may prohibit shipment of dilute acid more than 25 to 50 miles. The acid could be concentrated but this would entail additional cost.

Combustion Engineering Process--Combustion Engineering has developed and sold systems to utilities for flue gas desulfurization(7,10,11). Two of these units are presently undergoing demonstration. The following objectives for the process were established:

1. A system not dependent upon the sale of a chemical.
2. Reduction of SO_2 and particulate matter to such a level that the stack height and cost could be reduced.
3. Use of a less expensive dust collector than presently used.
4. The potential of increased boiler thermal efficiency without corrosion through lower exit gas temperature levels.

5. Reduction of high temperature fire-side coal-ash or oil-ash corrosion.

The system developed by Combustion Engineering to fill these requirements is shown in Figure 17. This system involves the feeding of an alkaline earth additive into the furnace and wet-scrubbing the flue gas leaving the air heater. The pulverized additive fed into the furnace is calcined, producing a more reactive compound. The calcined particles react with the combustion gases to form compounds of calcium and magnesium, removing 20 to 30 percent of the sulfur oxides including all of the SO_3.

The flue gas containing the unreacted SO_2 and calcined additive then passes into the wet scrubber. In the scrubber, the calcined additive that has not yet combined with SO_2 in the furnace reacts with the water and remaining SO_2 to form sulfates and sulfites of calcium and magnesium while the water entrainment of the fly ash results in particulate matter removal.

The solution containing the reacted materials drains out the bottom of the scrubber to a settling tank (clarifier) or pond. Here the particulate matter settles out. The cleansed flue gas passes through a demister for removal of the remaining water in the gas and is then reheated for induced-draft fan protection.

Operation has revealed problems and information not evident during initial pilot plant operation. Modifications to these systems have been made in the area of additive injection, gas distribution, and water control. Operation has confirmed that a SO_2 removal efficiency equivalent to burning a coal with less than 0.5 percent sulfur can be attained and greater than 99 percent particulate matter removal can be achieved when firing 3.4 percent sulfur coal.

Oxides of Nitrogen--Combustion Engineering has done much work in the area of oxides of nitrogen reduction. Oxides of nitrogen are formed at high temperatures by the reaction of the nitrogen in the fuel and the oxygen and nitrogen in the combustion air. The concentration of NO_x in flue gas depends on many factors involving burner and boiler design and operation. No generalization can be made regarding the effect of these variables and extensive studies of NO_x emissions(12-14) have shown that the exact level of emission from a particular unit cannot be accurately predicted.

Most research on oxides of nitrogen emissions has been done with oil and gas fuels. The general ranges for these fuels with horizontal and tangential firing are listed in Table I.

Data obtained at several plants for oil and gas firing are shown in Figures 18 and 19. At the O_2 levels present during conventional operation, a decrease in excess air produces a decrease in NO_x formation. The effect is particularly pronounced for horizontal firing. In recent years, there has been a trend towards operation of oil-fired units at low excess air levels of 2 to 5 percent (0.4 to 1 percent O_2) insteand of the conventional 10 to 20 percent (2 to 4 percent O_2). This has been done to minimize problems associated with the formation of SO_3. However, as indicated above, low excess air operation is also beneficial from the standpoint of reducing NO_x .

In addition to these methods of limiting NO_x formation, other methods such as overfire air, water injection, recirculation of combustion gases, and combination of these techniques, which reduce flame temperatures, have a favorable effect. Design features found to influence NO_x production are burner configuration, location, and spacing; furnace configuration; and the combustion method used.

Control of Air Pollution by Dispersion

Once the polluting process has been examined for possible modification to reduce pollutants and collection techniques have been applied, the waste gas and remaining pollutants must then be properly introduced into the atmosphere. If the contaminants are introduced into the atmosphere in such a manner that local concentrations are not harmful, the atmosphere, which possesses a tremendous capacity for self-purification, will dispose of this material. This atmospheric cleansing provides particulate fallout as either free material or the nuclei of water drops, while gases may be absorbed by particulate matter, dissolved in water drops, or condensed before returning to earth. All of this takes place during the normal movement of air and is quite effective if the atmosphere is not overloaded. Stack height and plume rise, as well as the amount of pollutant emitted, are important parameters in determining peak surface concentrations Contrary to popular belief, the tall stack, as compared to a short stack, does not "dump" the same amount of pollutants onto someone else farther away. Assuming the same mass emission rate, surface concentrations are lower at every point downwind, as the stack height is increased. On the other hand, even a tall stack may be overloaded in terms of meeting air quality standards if the amount of polluting effluent is excessive.

The stack is, then, an important part of any system for controlling air pollution. Some researchers have indicated that stacks are the only economically acceptable solution to the SO_2 and SO_3 problem(15). High level dispersion and dilution is no problem at the present time and this is an effective solution when coupled with other methods of control. If the quantities of material requiring disposal continue to increase, a problem may develop and the high stack may prove to be only an interim solution.

The concept of atmospheric dispersion may be questioned by those who have heard of the effects of air pollution during a thermal inversion and other adverse meteorological conditions. Thermal inversion of the atmosphere is one of the most severe natural "road blocks" to proper dispersion. This atmospheric condition is defined as a temperature increase with height rather than the normal decrease. (See Figure 20.) This restricts the vertical dispersion of the polluted air parcel, and since this condition is nearly always accompanied by low wind velocity, it tends to trap and concentrate pollutants. Normally, this is a natural phenomena occurring infrequently, and is somewhat peculiar to certain geological locations, although they are found in all parts of the United States. Valleys are most susceptible. During clear weather, the earth's surface responds rapidly to both daytime heating and radiation of heat from the surface at night. At night, the surface cools quickly, lowering the temperature of the surface air. Cold air accumulates at ground level causing an inversion because of the warm air trapped above. (See Figure 21.) This type of inversion is established in early evening and can persist for varying lengths of time. Material that is introduced into the atmosphere below the inversion level can be trapped and reach dangerous concentration. If sufficient stack height is used, the plume will break through the inversion emerge above it, and the surrounding countryside will be protected by the isolating effect of the inverted layer.

There are many factors to be considered in designing stacks for proper dispersion. Hill tops always present a problem (Figure 22) because air flow patterns about them can cause the pollutant to be returned to the floor of the valley as well as polluting the area at the top of the hill. In addition to this, the top of the inversion will frequently be at or near the height of the surrounding hill tops.

High stacks are very popular today as a means of insuring the dispersion of pollutants from combustion processes. Stacks 1000-feet high are presently under construction by utilities and this height is augmented by a high efflux velocity of about 75 feet per second. These factors, coupled with the buoyancy of the hot flue gas, produce an effective stack height which is substantially greater than the physical stack height (Figure 23). (The effective stack height is the sum of the actual stack height plus the height effects due to velocity and buoyancy.)

If the effective stack height is great enough, the effluent can "punch through" the inversion and disperse at higher elevations. The ability to pierce the inverted layer and to flow aloft above it and parallel to the earth's surface is a highly effective means of insuring adequate dispersion. If extremely severe pollution conditions exist, temporary correction can be made by changing fuel. With a sufficiently high stack, such correction would be needed only occasionally for brief periods. Referring again to Figure 23, it should be noted that minor low-level sources of pollution may be much more serious offenders than plants with high effective stacks.

Conclusion

Air pollution is emitted to some degree from nearly all combustion activities. The pollutants include the following: particulate matter and gaseous pollutants. These can be controlled to an acceptable degree if modern technology is applied.

The first consideration when seeking solutions to an air pollution problem is to evaluate the possibility of revamping the offending combustion process. If it is suspected that a new plant will be a polluter when erected, the designers should take advantage of the systems and components that are available today to minimize or eliminate air pollution. Many of these are discussed in this paper. With the exception of some of the systems to control gaseous pollutants, the state of the art is sufficient to limit air pollution. Of course, the equipment must be of good design and properly installed, operated, and maintained. Efforts are constantly being made to improve air pollution control equipment and reduce costs.

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U.S. Department of Health, Education and Welfare Control Techniques, AP Series.

TABLE I

Fuel	Firing	ppm NO_x
Oil	Horizontal	500 to 700
Oil	Tangential	200 to 400
Gas	Horizontal	300 to 500
Gas	Tangential	100 to 200

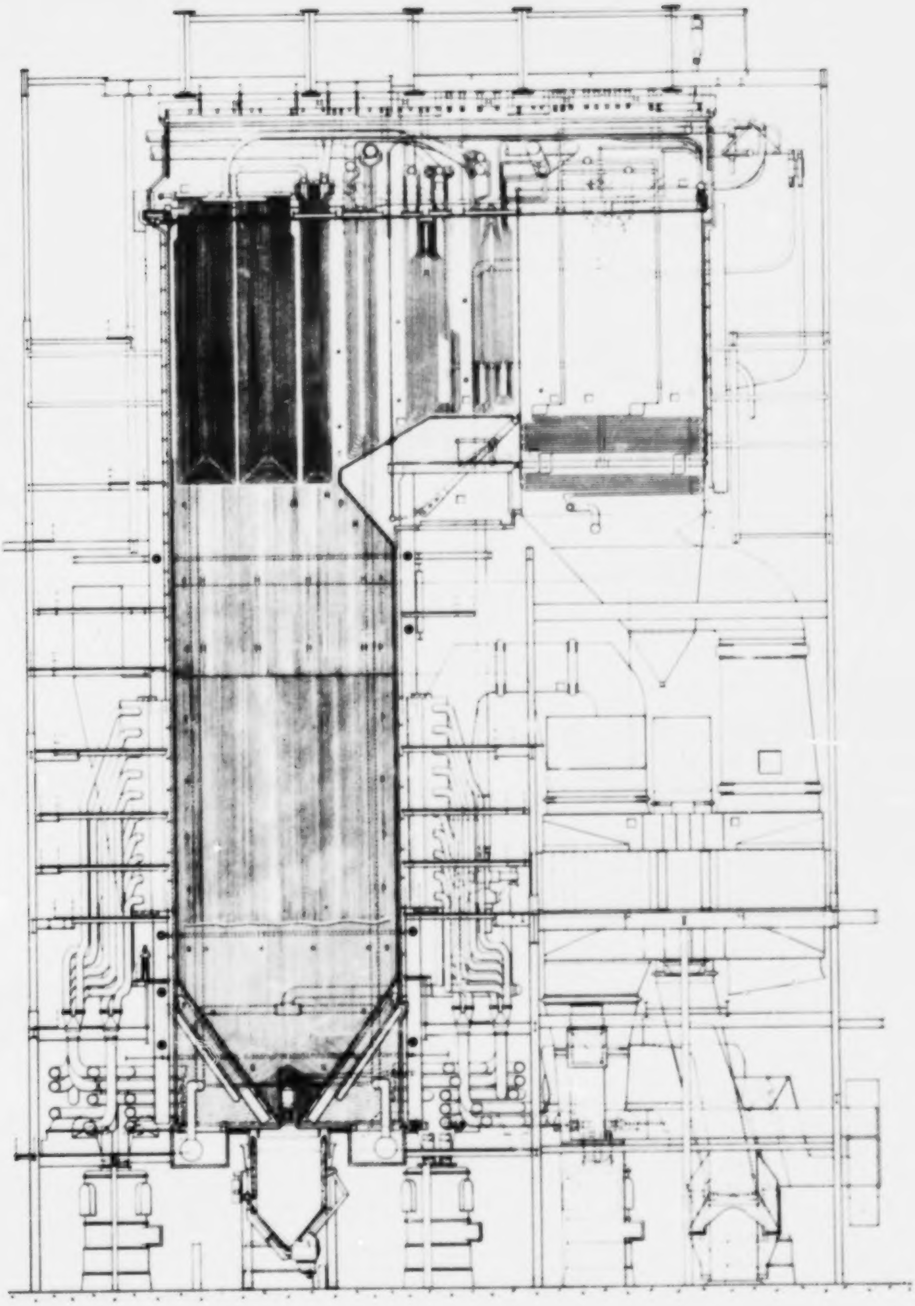


Figure 1: Side Elevation of Modern Steam Generator

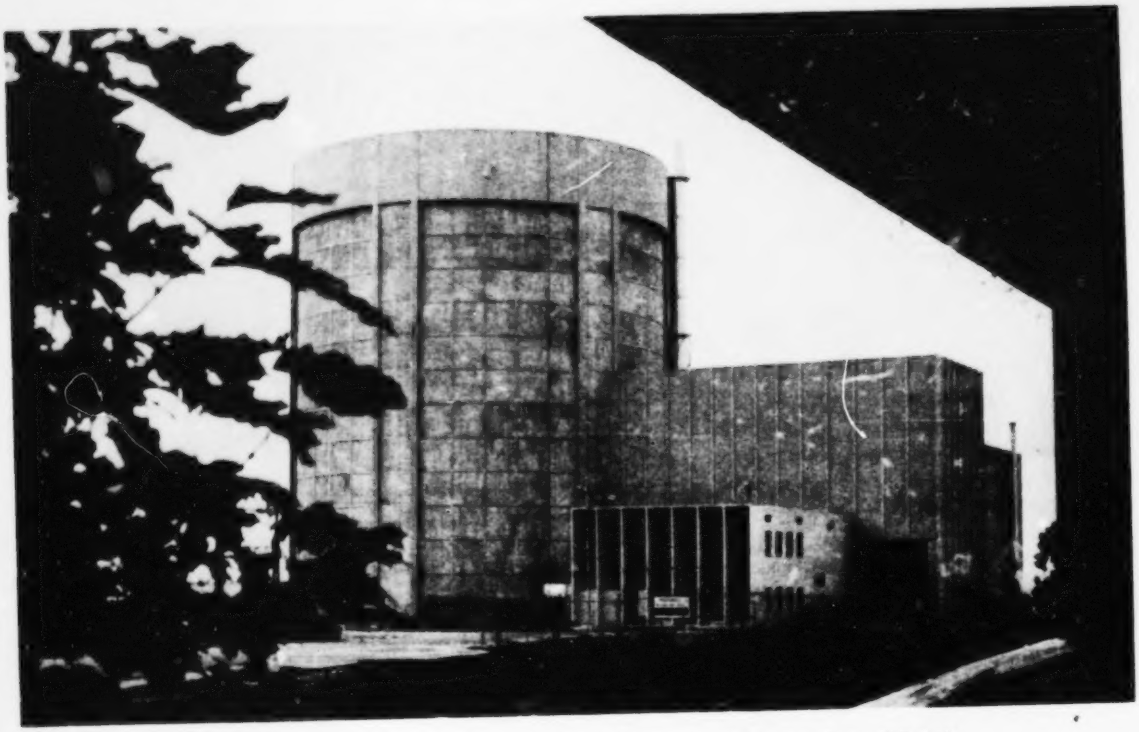


Figure 2: Palisades Nuclear Power Generating Plant

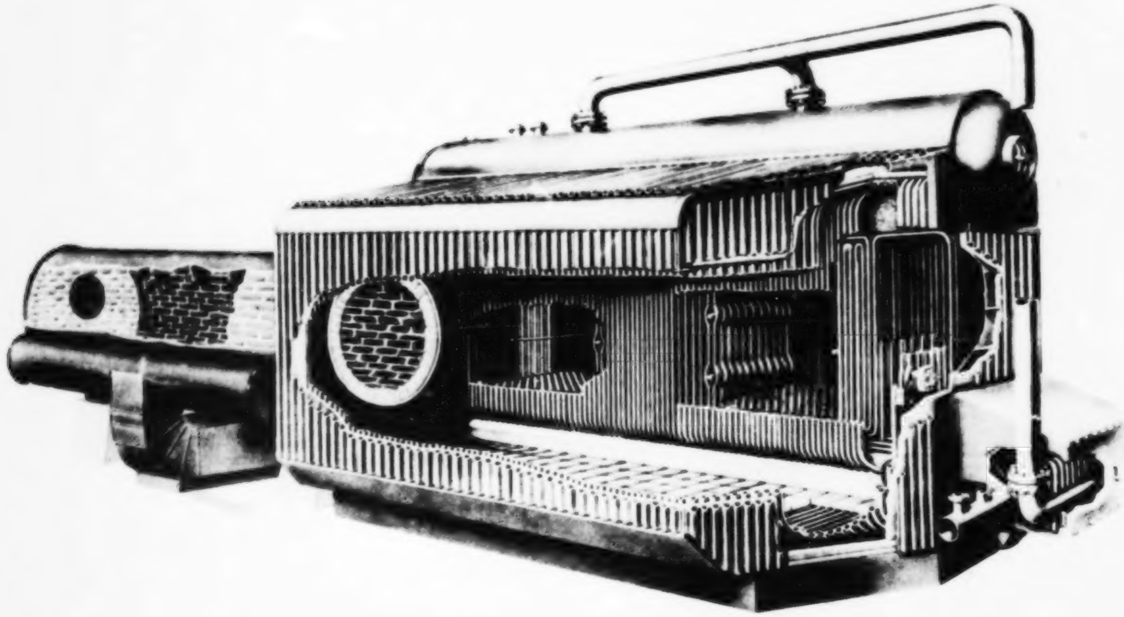


Figure 3: Shop-Assembled Boiler with Loddby Furnace

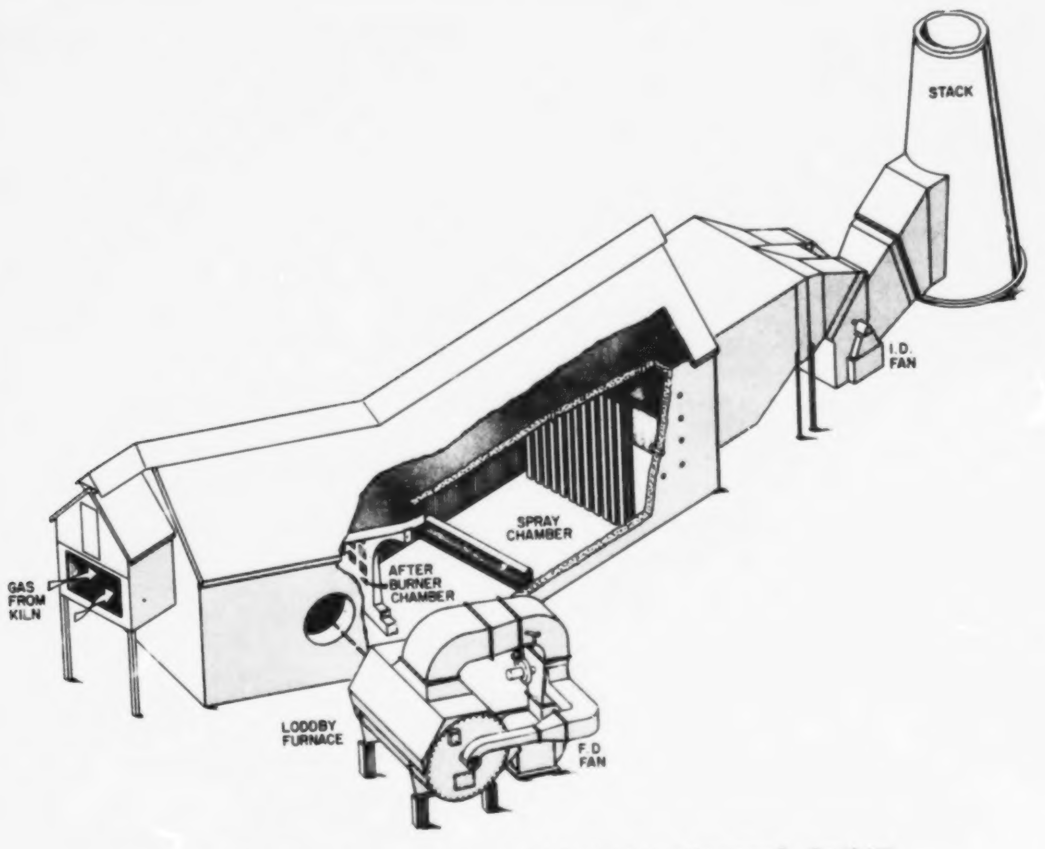

STACK
I.D. FAN
SPRAY CHAMBER
AFTER BURNER CHAMBER
GAS FROM KILN
LODDBY FURNACE
F.D FAN

Figure 4: Liquid and Solid Waste Disposal System

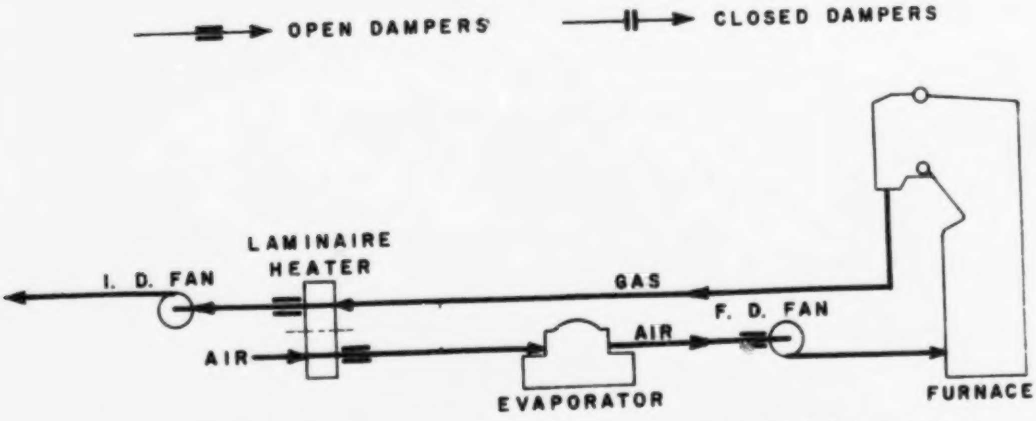

OPEN DAMPERS
CLOSED DAMPERS
LAMINAIRE HEATER
I. D. FAN
GAS
AIR
F. D. FAN
AIR
EVAPORATOR
FURNACE

Figure 5: Schematic of Air Contact Evaporator (ACE) System

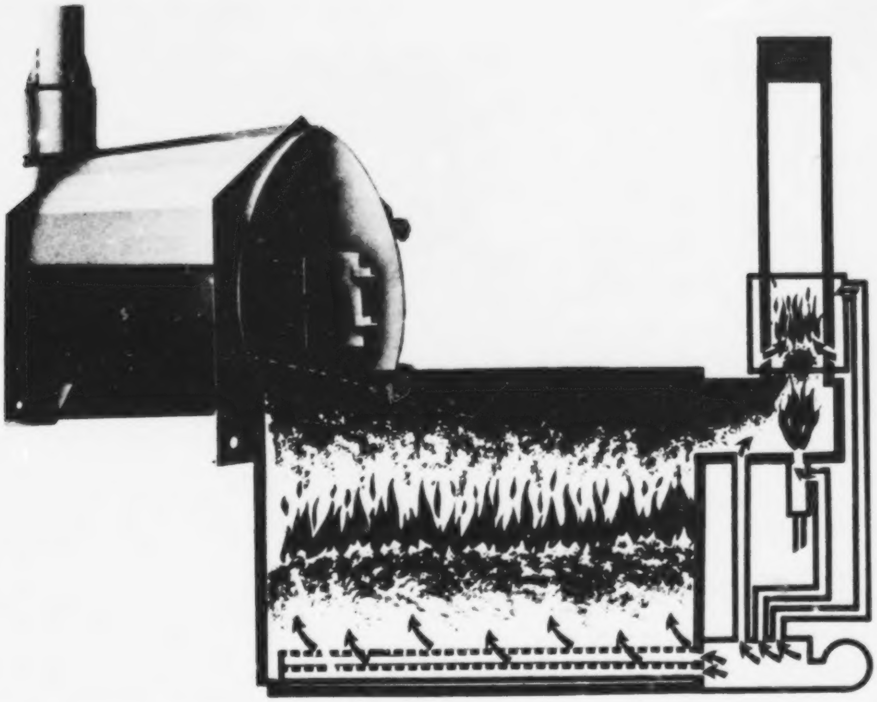


Figure 6: Combustall^{TM} Incinerator

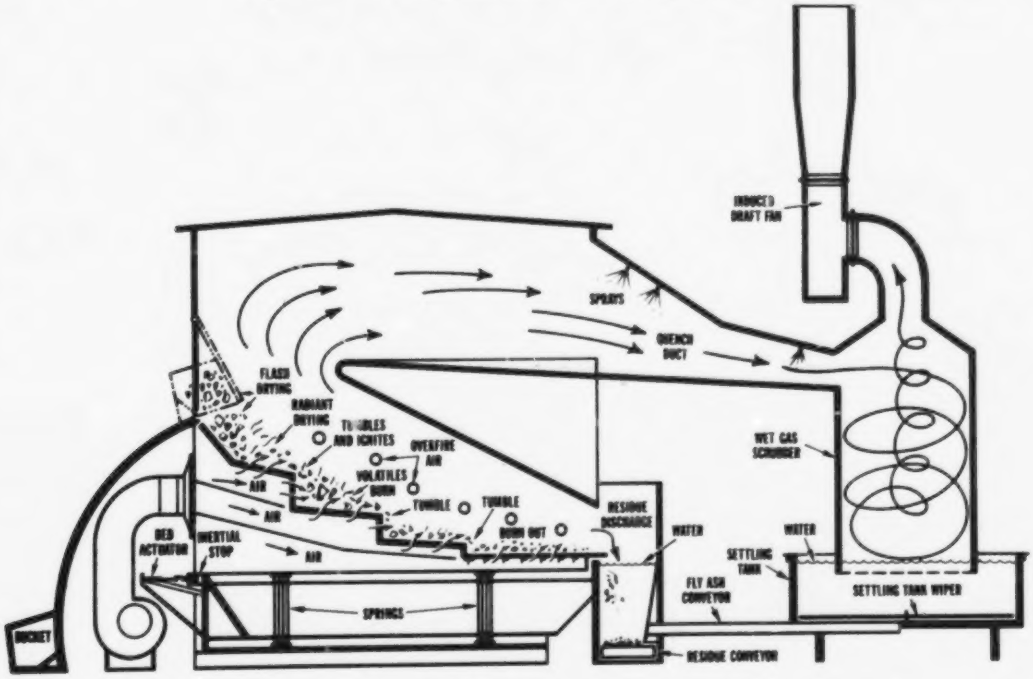

INDUCED DRAFT FAN
SPRAYS
QUENCH DUCT
FLASH DRYING
RADIANT DRYING
TUMBLES AND IGNITES
OVERFIRE AIR
VOLATILES BURN
TUMBLE
TUMBLE
BURN OUT
AIR
AIR
AIR
BED ACTUATOR
INERTIAL STOP
RESIDUE DISCHARGE
WATER
WATER
WET GAS SCRUBBER
SETTLING TANK
FLY ASH CONVEYOR
SETTLING TANK WIPER
SPRINGS
BUCKET
RESIDUE CONVEYOR

Figure 7A: Combustopak^{TM} Incinerator---General Layout

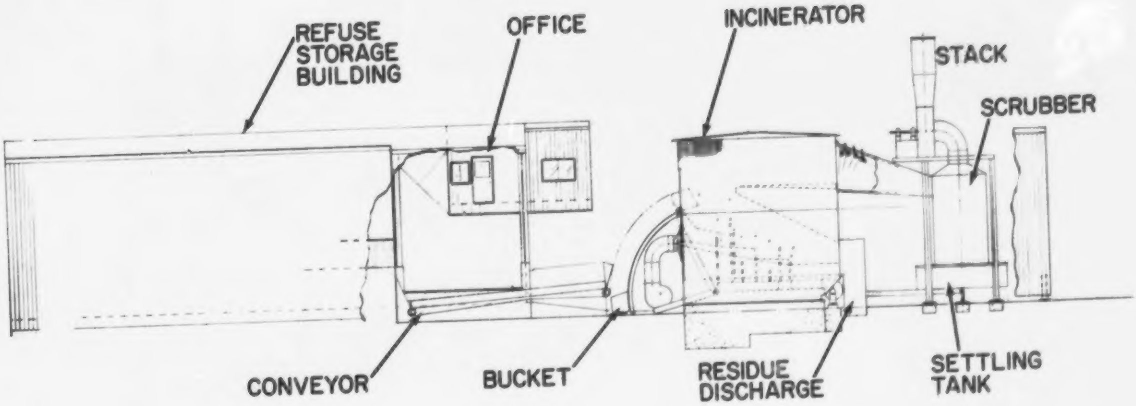

REFUSE STORAGE BUILDING
OFFICE
INCINERATOR
STACK
SCRUBBER
CONVEYOR
BUCKET
RESIDUE DISCHARGE
SETTLING TANK

Figure 7B: Combustopak^{TM} Incinerator---Detail of Incinerator and Scrubber

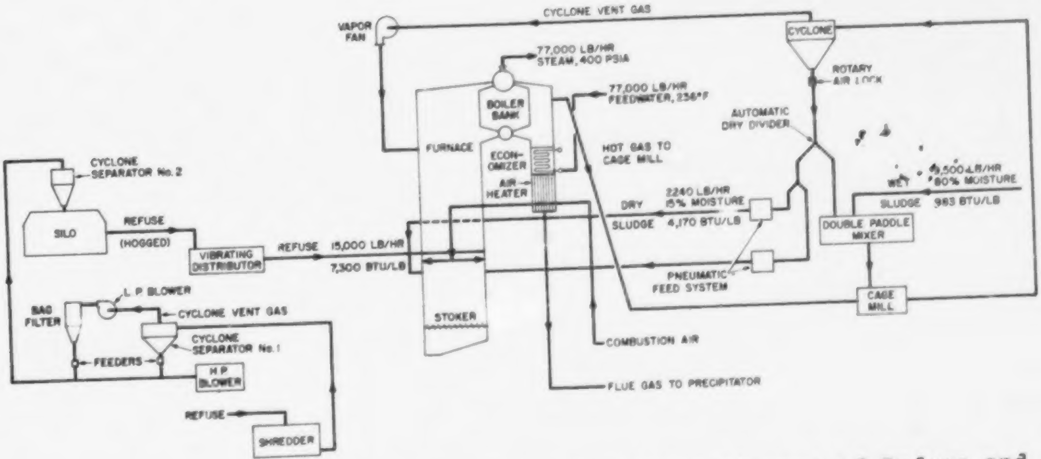

CYCLONE VENT GAS
VAPOR FAN
77,000 LB/HR STEAM, 400 PSIA
77,000 LB/HR FEEDWATER, 236°F
CYCLONE
ROTARY AIR LOCK
AUTOMATIC DRY DIVIDER
BOILER BANK
FURNACE
ECON-OMIZER
AIR HEATER
HOT GAS TO CAGE MILL
CYCLONE SEPARATOR No. 2
SILO
REFUSE (HOGGED)
VIBRATING DISTRIBUTOR
REFUSE 15,000 LB/HR 7,300 BTU/LB
DRY SLUDGE
2240 LB/HR 15% MOISTURE 4,170 BTU/LB
WET SLUDGE
9,500 LB/HR 80% MOISTURE 983 BTU/LB
DOUBLE PADDLE MIXER
PNEUMATIC FEED SYSTEM
CAGE MILL
L.P. BLOWER
BAG FILTER
CYCLONE VENT GAS
CYCLONE SEPARATOR No. 1
FEEDERS
H.P. BLOWER
STOKER
COMBUSTION AIR
FLUE GAS TO PRECIPITATOR
REFUSE
SHREDDER

Figure 8: Flash Drying and Burning System to Dispose of Refuse and Sludge

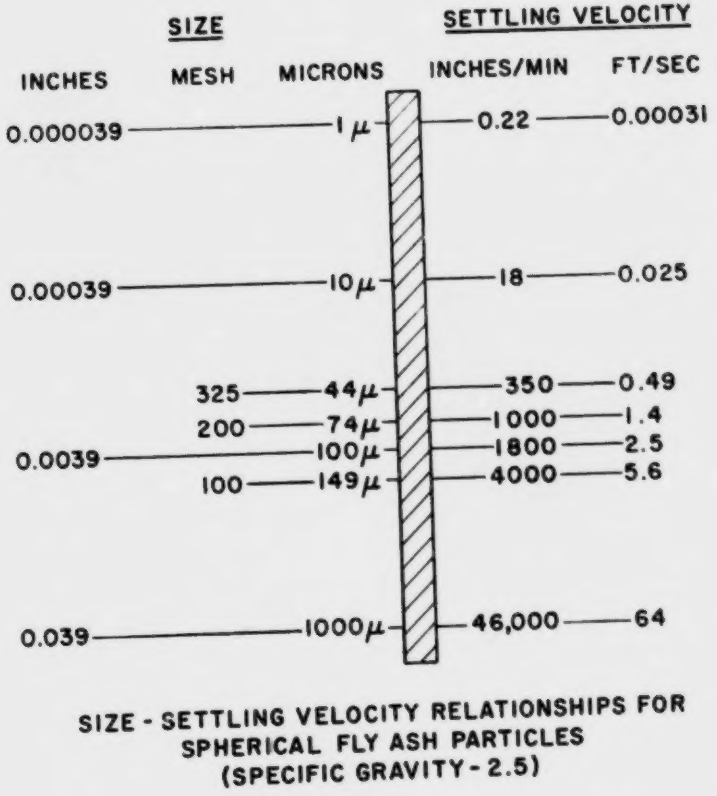


Figure 9: Size Settling Velocity Relationships

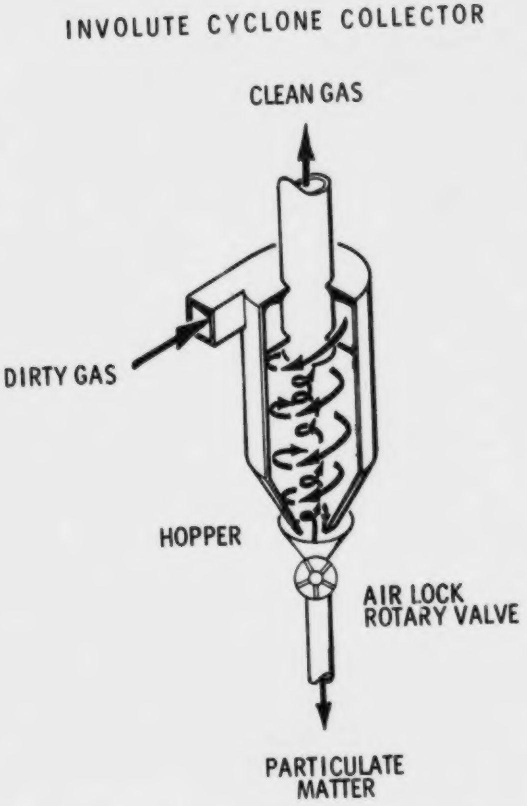

INVOLUTE CYCLONE COLLECTOR
CLEAN GAS
DIRTY GAS
HOPPER
AIR LOCK
ROTARY VALVE
PARTICULATE
MATTER

Figure 10: Infolute Cyclone Collector

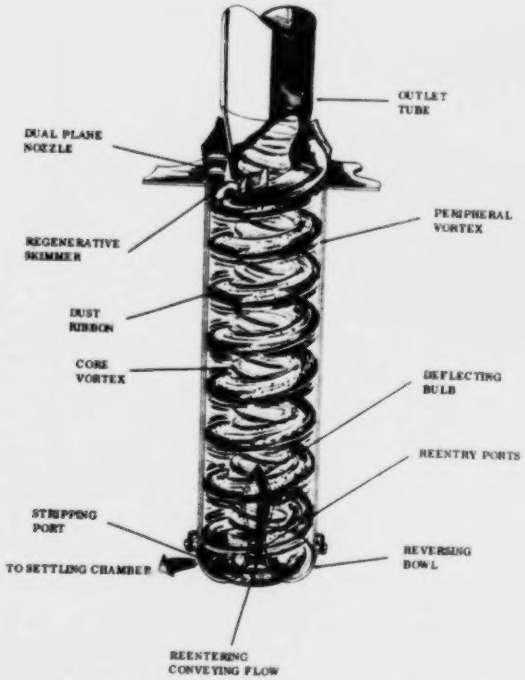
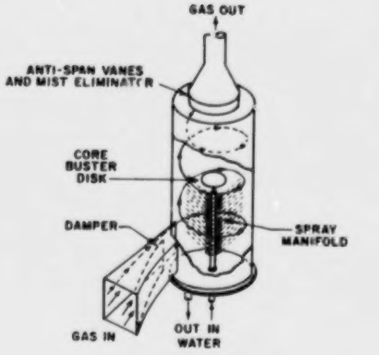
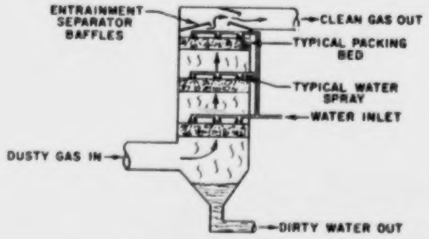

OUTLET TUBE
DUAL PLANE NOZZLE
PERIPHERAL VORTEX
REGENERATIVE SKIMMER
DUST RIBBON
CORE VORTEX
DEFLECTING BULB
REENTRY PORTS
STRIPPING PORT
TO SETTLING CHAMBER
REVERSING BOWL
REENTERING CONVEYING FLOW

Figure 11: Twin Cyclone Mechanical Dust Collector

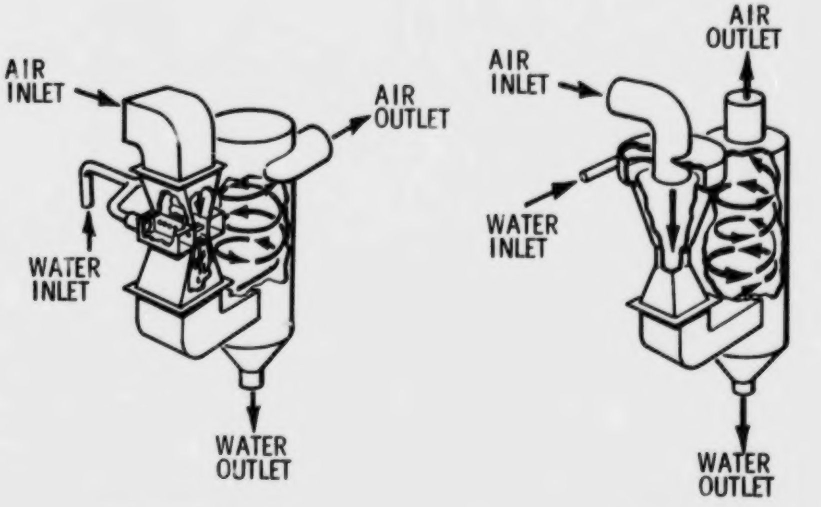

GAS OUT
ANTI-SPAN VANES AND MIST ELIMINATOR
CORE BUSTER DISK
DAMPER
SPRAY MANIFOLD
GAS IN
OUT IN
WATER

CYCLONIC SPRAY SCRUBBER


ENTRAINMENT SEPARATOR BAFFLES
CLEAN GAS OUT
TYPICAL PACKING BED
TYPICAL WATER SPRAY
WATER INLET
DUSTY GAS IN
DIRTY WATER OUT

PACKED SCRUBBER

Figure 12
Cyclonic Spray Scrubber (Top) and
Packed-Bed Scrubber (Bottom)


AIR INLET
AIR OUTLET
WATER INLET
WATER OUTLET
AIR INLET
AIR OUTLET
WATER INLET
WATER OUTLET

DRY VENTURI

WET VENTURI

Figure 13: Venturi Scrubbers

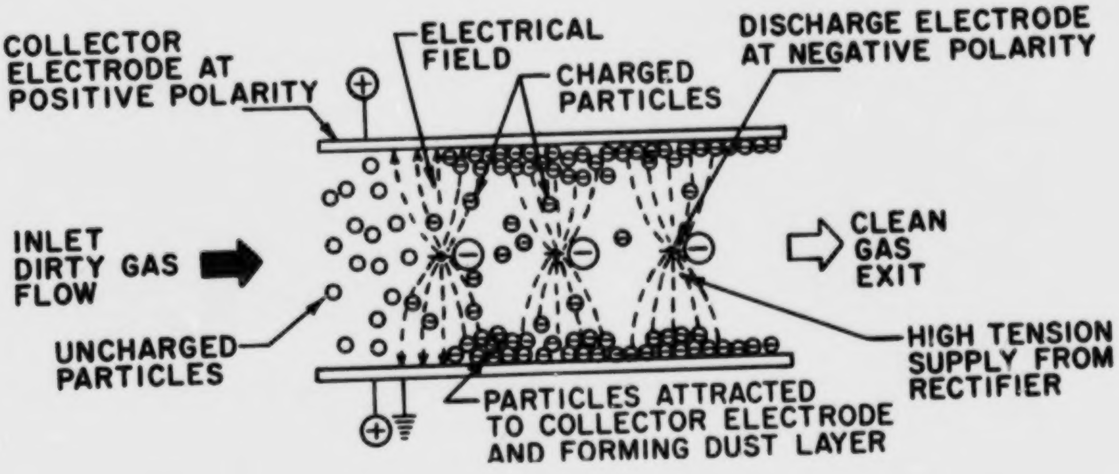

COLLECTOR ELECTRODE AT POSITIVE POLARITY
ELECTRICAL FIELD
CHARGED PARTICLES
DISCHARGE ELECTRODE AT NEGATIVE POLARITY
INLET DIRTY GAS FLOW
CLEAN GAS EXIT
UNCHARGED PARTICLES
HIGH TENSION SUPPLY FROM RECTIFIER
PARTICLES ATTRACTED TO COLLECTOR ELECTRODE AND FORMING DUST LAYER

Figure 14: Principle of Electrostatic Precipitator Operation

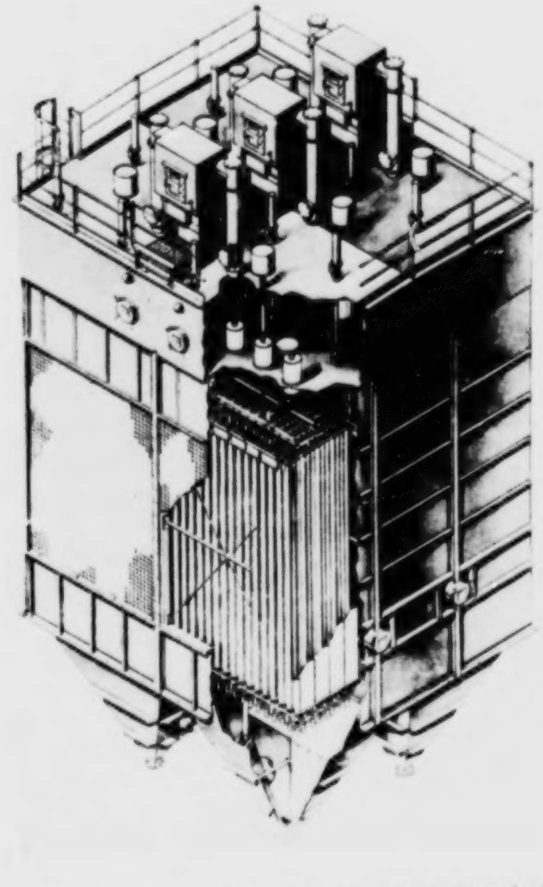


Figure 15: Cut Away of Typical Precipitator

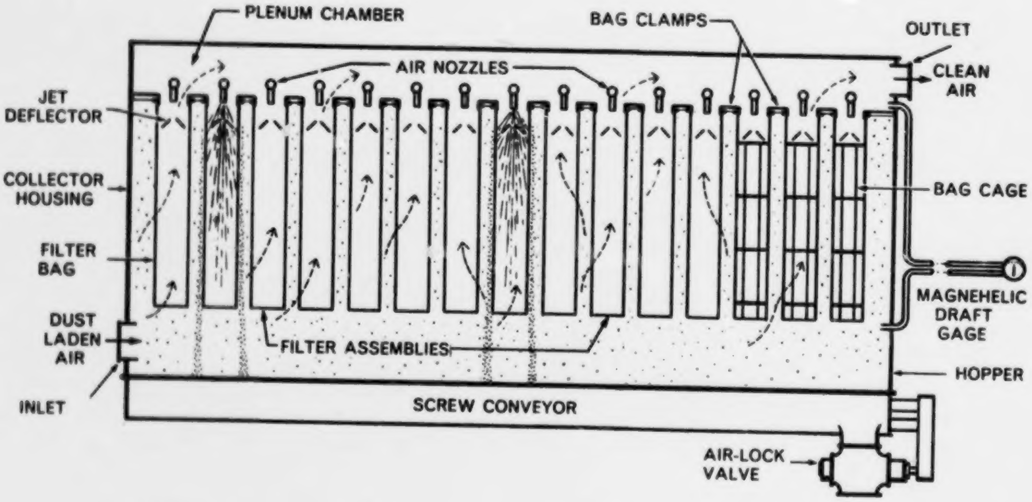

PLENUM CHAMBER
BAG CLAMPS
OUTLET
AIR NOZZLES
CLEAN AIR
JET DEFLECTOR
COLLECTOR HOUSING
BAG CAGE
FILTER BAG
MAGNEHELIC DRAFT GAGE
DUST LADEN AIR
FILTER ASSEMBLIES
HOPPER
INLET
SCREW CONVEYOR
AIR-LOCK VALVE

Figure 16: Ray-Jet Fabric Filter Dust Collector

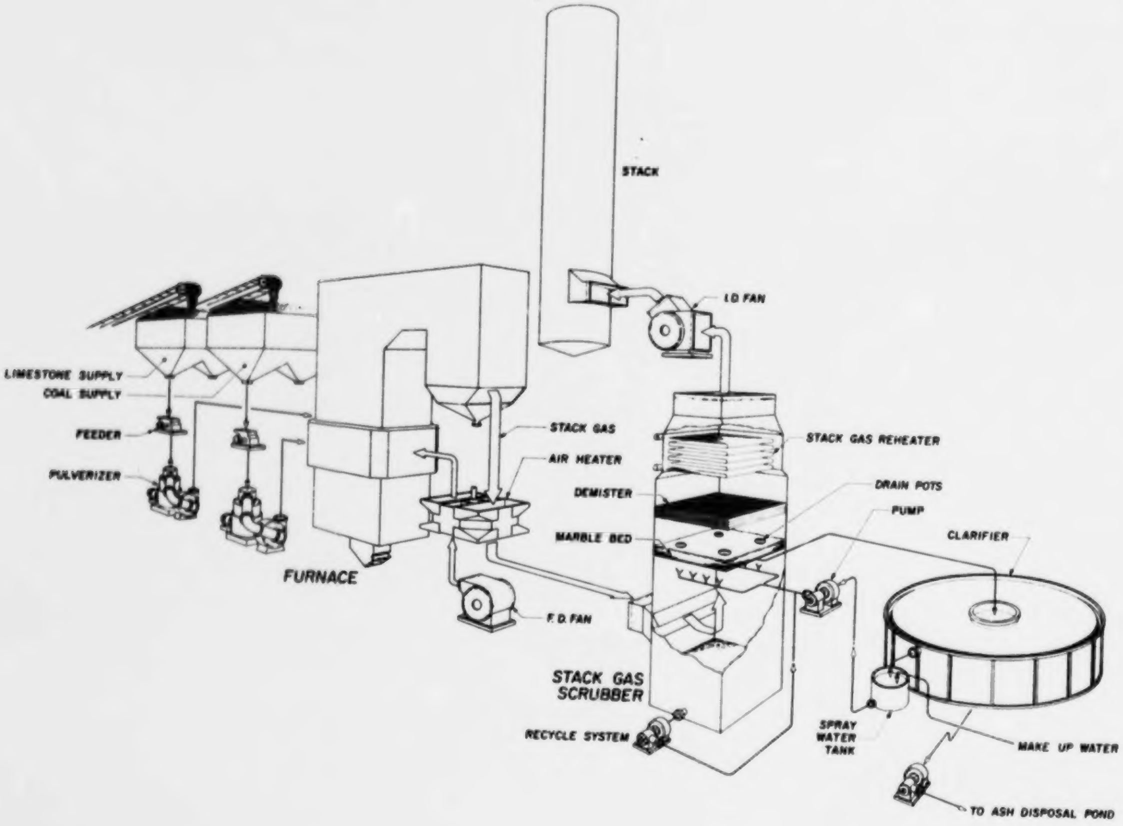

STACK
I.D FAN
LIMESTONE SUPPLY
COAL SUPPLY
FEEDER
PULVERIZER
STACK GAS
AIR HEATER
STACK GAS REHEATER
DEMISTER
DRAIN POTS
PUMP
MARBLE BED
CLARIFIER
FURNACE
F.D. FAN
STACK GAS SCRUBBER
RECYCLE SYSTEM
SPRAY WATER TANK
MAKE UP WATER
TO ASH DISPOSAL POND

Figure 17: Schematic of C-E SO and Dust Removal System

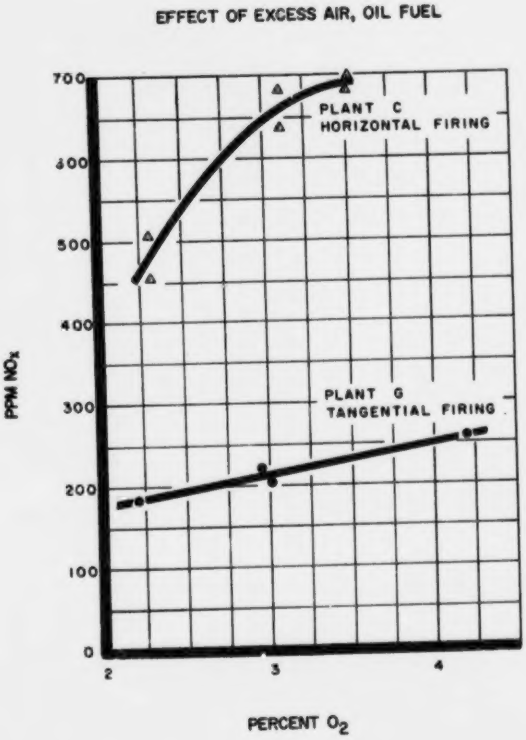


Figure 18: Effect of Excess Air, Oil Fuel

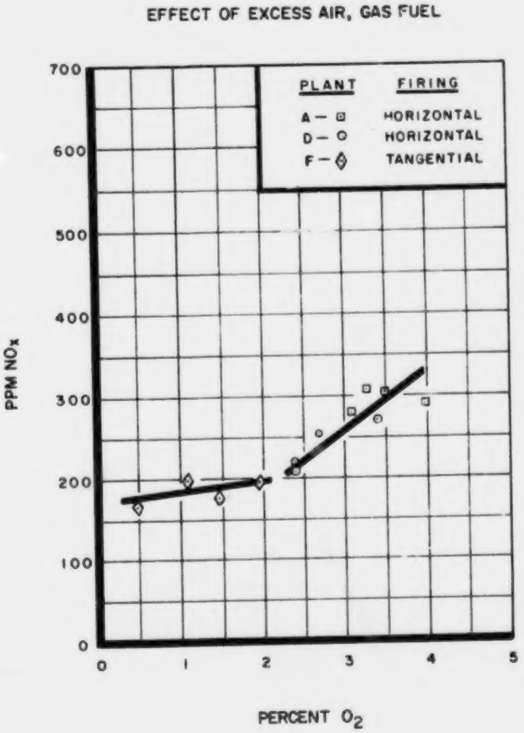


Figure 19: Effect of Excess Air, Gas Fuel

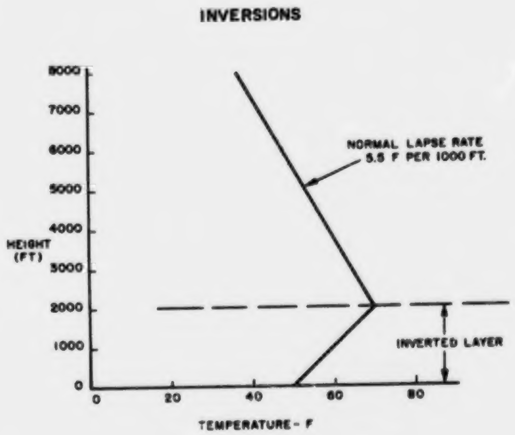


Figure 20: Inversions

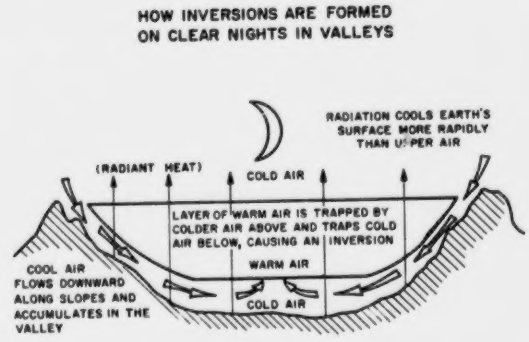

HOW INVERSIONS ARE FORMED ON CLEAR NIGHTS IN VALLEYS
RADIATION COOLS EARTH'S SURFACE MORE RAPIDLY THAN UPPER AIR
(RADIANT HEAT)
COLD AIR
LAYER OF WARM AIR IS TRAPPED BY COLDER AIR ABOVE AND TRAPS COLD AIR BELOW, CAUSING AN INVERSION
WARM AIR
COLD AIR
COOL AIR FLOWS DOWNWARD ALONG SLOPES AND ACCUMULATES IN THE VALLEY

Figure 21
How Inversions are Formed on Clear Nights in Valleys

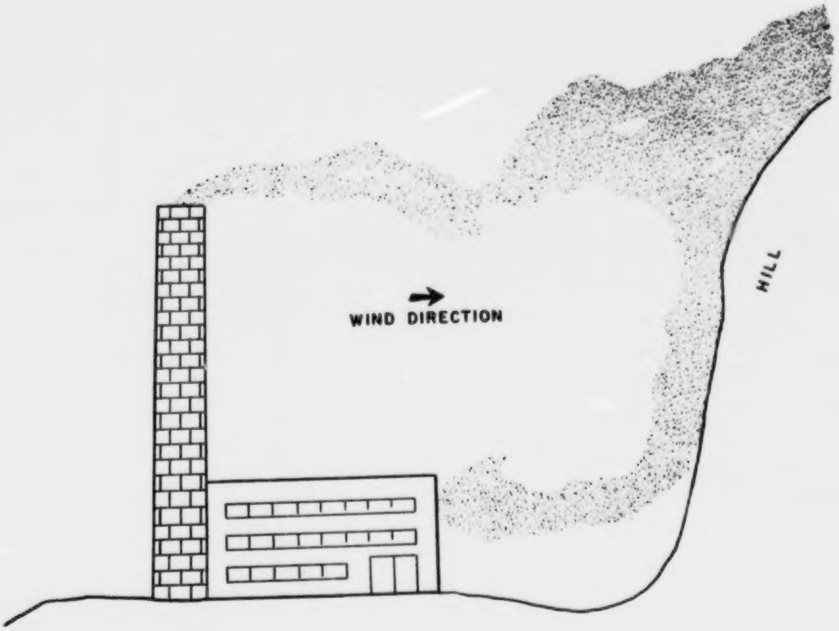

WIND DIRECTION
HILL

Figure 22: Effect of Hills on Air Flow Patterns

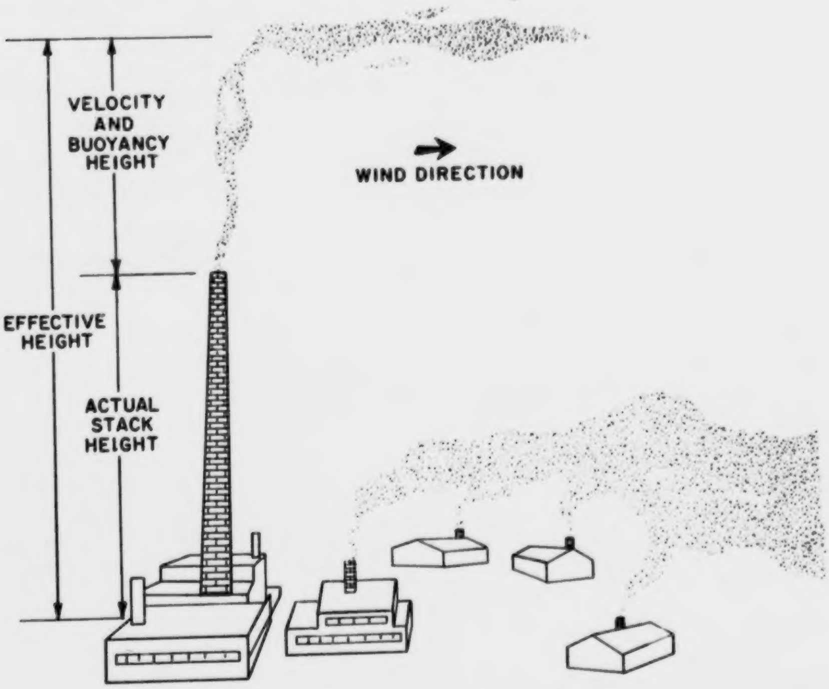

VELOCITY AND BUOYANCY HEIGHT
EFFECTIVE HEIGHT
ACTUAL STACK HEIGHT
WIND DIRECTION

Figure 23: Effective Stack Height Equals Actual Stack Height Plus Velocity and Buoyancy Factors

THE CONTROL OF INDUSTRIAL AIR POLLUTION SOURCES

By Alleu D. Brandt, Manager, and
David M. Anderson, Assistant Manager
Environmental Quality Control Division
Bethlehem Steel Corporation
Bethlehem, Pa. USA

Air pollution control from industrial sources in the U.S.A. was practiced sparsely until about 20 years ago. The early application of air pollution control facilities related principally to isolated sources having huge emission rates which created severe problems of local nature. The problems were either because of odor, surface discoloration or some other particularly objectionable characteristic such as denuding the nearby countryside or creating tremendously high dust fall rates. There is no need here to recount those episodes; suffice it to mention the Trail BC smelter case(1) as one of the very early incidents, and the many paper-making community odor problems which have been of concern during more recent times.

In our judgment, it was the Donora(2) incident in 1948 which alerted all segments of society in the U.S.A. to the serious health hazard that can be created whenever severe meteorological conditions exist over a local area which includes major sources of pollutants, the principal ingredients of which frequently are sulfur oxides and fine particulates. To be sure, that episode was unique, but it made many, many persons in the U.S.A. conscious of the potentialities that exist in numerous locations if adverse meteorological conditions should persist for days.

The anticipated result has come to pass. Society, government, industry, public health-oriented personnel and many other groups became concerned, and active. The degree of concern and rate of activity was further accelerated by the realization that conditions were becoming rapidly worse as a result of the combination of a population explosion and an unprecedented increase in the standard of living in the U.S.A. Both the population explosion and the increase in the standard of living promised ever-increasing air pollutant emission rates, including previously unheard of types of pollutants from more and more sources.

The past 20 years in the U.S.A. have seen major changes take place. Laws relating to air pollution control have been enacted and amended rapidly by and at all levels of government; society has become conscious that the private citizen as well as industry, the automobile and the municipal incinerator all contribute to the problem. One important result has been that the rate of application of air pollution control facilities and process changes to achieve emission reduction have catapulted to new highs year by year, especially during the past three to five years. Much remains to be done, but the need to do and the will to do even more now are evident to a degree never experienced previously in the U.S.A. Even though industry in the U.S.A. continues to be as competition-minded as ever, industrial captains across the nation have made it abundantly clear in the past year or two that continued degradation of the environment must be stopped, and that the well-being of society--the quality of the environment--has top priority even if it conflicts with other business considerations.

Significantly, efforts to control air pollution have increased in the past two years, a period during which profits have fallen. According to a recent Federal government projection(3), the total investment required to control air pollution from the major process industries between 1970 and 1976 is approximately 3.9 billion dollars. The annualized cost, including operating and maintenance costs, is approximately 1.1 billion dollars (see Table I). These figures do not include, however, the untold expenses incurred before 1971.

Let's take a look at the major pollution sources in the United States. Table II shows the relative quantity of total air pollutants (particulate and gaseous combined), emitted from the major pollutant classifications in 1968(4). Note that the industrial portion, 30 million tons, is only 14% of the total quantity of emissions. This emission rate, and the other emission rates mentioned in the table, are the amounts still to be controlled and do not include the great amounts of potential emissions which currently are being controlled.

Particulate matter(5,6) is the major pollutant released from most industrial processes (see Table III). Gaseous pollutants, such as sulfur dioxide(7), hydrocarbons(8), and carbon monoxide(9), are problems for a few specific industries (see Table IV). Fluoride (particulate and gaseous) emissions are also a problem for some industries. Because particulates are the number one industrial problem, we will describe the control efforts of each major industry in order of decreasing emission rate as estimated for 1967 (see Table III). The year 1967 is used as the baseline year to compare pollution control efforts in the United States in conjunction with passage of the 1967 amendment to the Clean Air Act. Efforts to control gaseous emissions will be described where applicable to a specific industry.

Particulate emissions occur in a variety of forms including dusts, fumes, mists, and smoke. Dust particles are relatively large as compared to fumes, some mists, and smoke, and generally are released from material crushing and handling operations. For the purpose of this paper, fumes are condensed metallic vapors; mists are liquid particles suspended in gas (usually air); and smoke is small particles of carbon suspended in the gaseous products of fuel combustion.

In discussing air pollutants from industrial sources it is important to always keep in mind the nature of the source, whether it be a captive source such as the stack from a metallurgical furnace or the vent from an enclosed chemical process, or whether it be a fugitive source such as a stream or cloud of dust-laden air or gas which is not contained. Typical examples of fugitive sources are dust from blasting operations in quarries and smoke from the charging of conventional vertical-slot ovens used in the by-product method of making coke from coal.

When one is dealing with a captive source of air pollutant, control can be achieved by removing the pollutant from the confined or contained gas (or air) stream of which it is a part. Thus controlling a captive source is purely a problem in gas (or air) treatment, the technology for which frequently is available, especially as regards the removal of particulate matter from stack and vent gases. However, control of a fugitive source is much more evasive because technology is frequently not available for capturing or containing certain fugitive sources. Before such clouds of fugitive emissions can be cleaned, they must be converted from fugitive to captive sources. Keeping haulageways or roadways from dusting in freezing weather; preventing settled dust from being refloated by wind gusts; containing the smoke, other particulate matter and gaseous pollutants which escape during charging of coke ovens; and preventing dust clouds from being generated when blasting or when farming during dry weather are problems still needing much improved control technology before they are amenable to control.

Control of particulate emissions from captive sources may be achieved through basic process changes and operational changes, or through particulate removal equipment. Treatment facilities include centrifugal separators, fabric filters, scrubbers, and electrostatic precipitators. Centrifugal separators (and some types of scrubbers) act as primary collectors and have low collection efficiencies for particles smaller than 5 microns. Fabric filters, high-energy (venturi) scrubbers, and electrostatic precipitators, on the other hand, are high efficiency collectors which can be made effective even against submicron particles. In many cases adequate control of industrial sources can be attained only through use of the high efficiency collectors. Sometimes, depending upon the nature of the source, combinations of process changes or of collectors are needed to achieve a satisfactory effluent.

It may be useful at this point to review the basic control mechanisms of the various collectors. Centrifugal collectors utilize centrifugal force created by spinning a particulate-laden gas stream to separate the particulates from the carrier gas Fabric filters remove particulates mostly by interception and impaction of the particulates initially with the fabric and later with the resultant dust cake formed on the upstream face of the fabric while the carrier gas passes through the fabric. Venturi scrubbers remove particulates by impacting the particles on water droplets and removing the particulate-laden water droplets in a mist eliminator. Electrostatic precipitators charge the particles with electrostatic charges and collect them on grounded surfaces.

Table III lists the major industrial particulate emission sources in the U.S.A. Surprisingly, the stone, sand and gravel industry is the largest single industrial source of particulate (dust) emissions. The dust occurs mostly during crushing and grinding and also during quarrying, transportation of materials, and size classification. In many cases the sources are not stationary and the emissions often occur intermittently, both of which conditions increase the difficulty of control. Fugitive sources can often be reduced by changing plant layout and material handling practices. The use of water sprays at critical points is the simplest and least expensive method of controlling dust from these sources, though this procedure is fraught with difficulty in sub-freezing weather.

Crushing and grinding operations in many industries other than the stone, sand and gravel industry also create problems. Most are amenable to control by proper hooding or other enclosures, exhaust ventilation of the sources and appropriate collectors. Where applicable, water sprays often provide the easiest solution.

The grain milling and handling industry which processes grain into flour, livestock feeds, and cereals is the second largest industrial source of particulate emissions. The dust emitted at the cleaning, milling, and handling operations of grain terminal elevators constitutes the majority of the problem. In many cases the value of the collected dust is sufficient to pay for the collection facilities. Dust generated from milling and handling of livestock feed often is uncontrolled because the feed is less valuable. The dust can be captured by exhausting air from hoods at transfer points and from grain elevators and cleaning the exhaust streams in fabric filters.

The iron and steel industry is the largest single industrial source of captive-type particulate emissions. Consequently, we will treat it in greater depth than any other industry source and it will serve as an example of the complex problems which industries face in controlling air pollution.

Iron and steel industry particulate emissions include dusts, fumes, smoke and mists. Dust is generated from some fugitive sources such as previously described, and from plants which sinter a mixture of ore, flue, dust, lime, iron scale, and coke breeze into a product acceptable for charging into the blast furnaces. In the process, the mixture is located on a moving grate, and the air which is pulled through the mixture to burn the fuel becomes hot, and laden with dust, moisture, and some sulfur dioxide. The resultant windbox effluent is corrosive and abrasive and until recent years has been cleaned almost exclusively by centrifugal separators, electrostatic precipitators having been used in only a relatively few instances. Precipitators installed in recent years often have performed rather poorly. Consequently, scrubbers and fabric filters now are being investigated for sinter plant windbox application. They were not considered previously largely because fabric filters are susceptible to clogging by moisture, and scrubbers create water pollution problems in addition to being susceptible to corrosion and abrasion. The decision as to what type of collector is most suitable is not yet clear. It will vary from plant to plant depending upon the nature of the feed materials.

Control of the dust released from the discharge ends of the sinter strands in sinter plants and certain subsequent conveyor transfer points and accessory processing operations has been accomplished reasonably well with available technology. Only within the past year or two has the dust generated by air-cooling the hot sinter come under consideration. While technology is available for controlling such dust the magnitude of the dust-laden air streams is so large that the cost of control of these dust-producing operations will be very high in terms of dollars per unit of particulate pollutant per hour recovered.

Fume is generated in ironmaking and steelmaking furnaces. Iron is produced in blast furnaces by smelting iron ore. Particulates contained in the off gas from the blast furnace operation are now and have for years been controlled well in order to permit using the blast furnace gas as a fuel, even though it is a very low grade fuel. Venturi scrubbers and/or wet-type electrostatic precipitators are utilized as the final stage in the gas-cleaning systems of blast furnaces.

Steel is produced in open hearth, basic oxygen, and electric furnaces. The raw materials are principally iron, either hot metal or "pigs," and scrap. Limestone, iron ore and alloying materials are used as required. Scrap is the principal raw material in most electric furnaces and in many "cold charge" open hearths.

Every basic oxygen furnace constructed in the U.S.A. has been provided with effective air pollution control systems in which precipitators or high-energy scrubbers serve as the particulate collectors. For the second half of 1970, more than half of the steel made in the U.S.A. was made in basic oxygen furnaces. The stack gases from all except a very few oxygen-lanced open hearth furnaces are now being cleaned effectively. However, because conventional and frequently "cold charge" open hearth furnaces create a comparatively small amount of particulate matter, and because of economics, such furnaces have seldom been controlled in the past. Many are now being retired or replaced by more up-to-date furnaces such as basic oxygen furnaces and electric furnaces.

Particulate emissions from electric furnaces are more difficult to control satisfactorily than from other steelmaking furnaces, because practically all electric furnaces can be charged only when the furnace top is swung aside. Since fume control during melt down, refining, etc. is achieved in many furnaces by direct evacuation of the furnace chamber through a connection in the furnace top, that system is inoperative during charging. As a result, the trend today is toward complete building ventilation (evacuation), usually through large compartmented hoods rather high above the furnaces (so as not to interfere with the bridge-type service cranes). While this solution to the problem is an effective one, it is inherently very inefficient and costly. All of the pollutants that are permitted to escape into the building housing the furnaces are diluted rapidly in the room air. Consequently, the amount of dirty air exhausted from the buildings which must be cleaned before discharge to the outside air is many times what it would be if control could be applied at the source. For example, a system having a capacity of about 100,000 cfm will control effectively the fumes generated in several electric furnaces during melt down, refining, etc., but the capacity of the system for the same furnaces must exceed 1,000,000 cfm if open furnace top charging is done, during which time the particulate pollutants escape from the furnace into the building. This large increase in capacity is needed even though the charging operation may account for less than 10% of the total particulate matter generated by the furnaces. Baghouses with glass fabric filters are the collectors normally used for direct evacuation systems, and baghouses with dacron fabric filters are normally used for building ventilation systems.

A combination of coal dust, hydrocarbon vapors, particulates, mists and smoke is emitted from coke plants, most of which in the U.S.A. are owned by iron and steel companies. Coke, a primary fuel for the blast furnace, is produced in vertical slot ovens through the destructive distillation of bituminous coal. Usually between 50 and 100 slot ovens constitute a coke oven battery which is shaped somewhat like a loaf of bread, each slice representing an individual oven. Coal is charged through openings in the top of each oven and coke is pushed from one end out the other. Emissions occur from leaks, coal charging and coke pushing. Adequate control of these emissions is not possible with today's technology. We are confident, however, that coke oven emission control will be technically feasible within the next few years. The entire steel industry, separately and trhough the American Iron and Steel Institute jointly with the federal government, is currently building or completely modifying several full-scale coke batteries with similar, though each somewhat different from the other, pollution control systems.

The kraft (sulfate) pulp industry emits particulates in the form of process chemicals. Pulp is manufactured from wood for use in making paper and related products. Wood chips are cooked in a liquor which separates the cellulose from the lignin. Pulp is then produced from the cellulose. The lignin is burned as a fuel in the recovery furnace and the chemicals are recycled. Process chemicals are released from recovery furnaces and smelt dissolving tanks, lime is released from recovery kilns, and char is released from bark boilers. Particulate emissions from recovery kilns are controlled with electrostatic precipitators; emissions from smelt dissolving tanks and recovery kilns are controlled with scrubbers and particulate emissions from bark boilers are reduced with centrifugal separators.

The asphalt batching industry is also an important source of particulate emission. Asphalt batching is the production of a road surface paving mixture made from hot asphalt and stone aggregate. Most of the particulates (dust) are emitted from the rotary dryers which pre-dry and pre-heat the stone aggregate before mixing it with the hot asphalt prior to the batching process. The drying and heating is normally done in rotary kilns which are rotating horizontal cylindrical furnaces slightly sloped so that the stone rolls by gravity from the charging to the discharging end. General practice is to reduce emissions by 80% or more with centrifugal separators. Scrubbers are necessary in order to accomplish adequate control. New plant capacity must be greater than 400 to 500 tons/day to economically allow for scrubber control.

The cement and lime industry are similar prcesses with similar emission problems. For both cement and lime, limestone or other calcium-bearing rock is calcined to produce calcium oxide. Both cement and lime are calcined in rotary kilns similar to those used by the asphalt industry. The capacity of cement kilns is as much as 10 times greater than the capacity of lime kilns. For both industries a large amount of dust entrained by the kiln gases must be controlled. For lime kilns, fabric filters or scrubbers are normally used, while for cement kilns, fabric filters or electrostatic precipitators are the usual choice. The difference in selection is a result of comparative economics for large cement kilns vs. small lime kilns.

The iron foundry industry, a large, diversified and scattered industry, produces castings such as machine and automobile parts, and in doing so, generates large amounts of particulate emissions. Over 90% of all the iron used by the industry is produced in cupolas. Cupolas are vertical cylindrical furnaces in which coke is burned in direct contact with the metal charge. The cupolas emit a large amount of particulate matter which consists of coke, oil, fume and lime dust. Most cupolas are adequately controlled in the U.S.A. Proper control equipment for cupolas in many instances is more expensive than the cupolas themselves. Some jobbing foundries which operate cupolas intermittently cannot afford to adequately control emissions and are, therefore, going out of business. Many foundries of larger industries are consolidating or centralizing cupolas operation in order to eliminate many of the cupolas. Furthermore, some cupolas are being replaced by electric arc and electric induction furnaces. Although both high efficiency scrubbers and fabric filters have been considered as effective collection devices for cupolas (where economically feasible), to our knowledge only scrubbers have been used on cupolas without difficulty.

Cupolas also emit large quantities of carbon monoxide. This gas can be eliminated at comparatively little cost by afterburners.

The coal cleaning industry is an important source of particulate (dust) emissions. The coal is cleaned of undesirable materials found in raw mine coal by washing the coal with air or water. The major amount of dust comes from either flash driers, fluidized-bed driers, or pneumatic cleaners. Scrubbers rather than fabric filters are preferred as control devices to avoid the fire and explosion hazard which exists with coal dust.

The petroleum refining and storage industry is a source of particulates, carbon monoxide, sulfur oxides, and hydrocarbons. Particulates, carbon monoxide, and hydrocarbons are emitted from the catalytic cracking units. The particulates are catalyst fines which are entrained in the off gases from the catalyst regenerator. Particulate control is best accomplished by electrostatic precipitators. The carbon monoxide and hydrocarbons released in the exit gas of regenerators are generally burned in waste heat boilers.

Large amounts of sulfur oxides are emitted from the refineries' practice of burning, as fuel, the low-grade, sulfur-bearing gas and liquid fuels which are generated in the refining processes. Sulfur oxides emission control can best be accomplished by removing the sulfur compounds from the fuel and feed stock by catalytic hydrogen treatment. Hydrogen treatment produces hydrogen sulfide which can be scrubbed from the gas stream, stripped from the scrubbing solution by heating, and converted to sulfur by conventional processes.

Most hydrocarbon emissions are evaporation losses from storage tanks and from the loading of tank trucks. Evaporation losses during storage are reduced trhough the use of floating storage tank roofs, pressure tanks and recovery systems. Vapors emitted during the loading of trucks can be collected and recovered in a vapor recovery system.

The sulfuric acid industry is a source of particulate (in the form of sulfuric acid mist) and sulfur dioxide emissions. Most sufuric acid is produced by burning sulfur or pyrite to produce sulfur dioxide which is catalyzed to sulfur trioxide which in turn is absorbed in weak acid. Acid mist emission can be readily controlled with either an electrostatic precipitator or mesh type mist eliminators. Sulfur dioxide which remains unconverted and subsequently is emitted, can be controlled by a secondary absorption column.

Particulate control practices of the non-ferrous metallurgical industries which produce aluminum, copper, zinc and lead need not be described here inasmuch as the fume sources and control techniques are similar to those of the iron and steel industry.

The primary non-ferrous metallurgical industry, however, is the largest industrial process source of sulfur oxides, and the second largest source of fluorides. The sulfur oxide emissions result from the smelting of copper-zinc, and lead-containing ores. Sulfur oxides can be significantly reduced by passing the captured gas through a sulfuric acid plant. Sulfur oxide emissions from the acid plant, however, may still be significant and require further scrubbing.

Fluoride emissions (a combination of particulate and gaseous fluoride) result from the production of primary aluminum in reduction cells. The cell gases are captured either at the point of evolution by separate hoods over the individual cells, or at the roof monitor by one large hood which captures the entire cell room ventilation flow. In the past, fluoride emissions have been reduced by greater than 90% by passing the captured gas through centrifugal collectors followed by low-energy scrubbers. The fluoride problem is completely controlled in new plants, however, by cleaning the gases in a fluidized bed followed by fabric filters or floating bed scrubbers.

The brick and tile industry is the largest source of fluoride emissions in the U.S.A. Gaseous fluorides are emitted during heating the brick and clay products in burning kilns. Emission data are sketchy and fluoride control has not been practiced. Emissions can be reduced to very low levels, however, by scrubbing the kiln gases with water. It should be noted that fluoride emissions do not occur, of course, where the clay does not contain fluorides.

Other less important industrial sources of particulate emissions in the U.S.A. include the phosphorous and phosphate fertilizer industry, the rubber industry, and many other less significant sources. Furthermore, there are many local problems resulting from a variety of specific pollutants such as lead and a variety of malodorous chemicals. Many of these sources must also be controlled.

There is a very good chance that most of the above-mentioned pollution sources in the U.S.A., with the possible exception of certain problem sources for which control technology is not currently available, will be controlled to a much greater extent than today within the next five to ten years. Great strides have already been made, and by the year 1980 it is expected the emission rate from industrial air pollution sources in the U.S.A. will be reduced by at least 90% from 1967 levels.

TABLE I

Projected Control Costs Between 1970 and 1976

Industrial Process Source[1]	Control Costs[2] (Millions of Dollars) Investment[3]	Annual[4]
Stone, Sand and Gravel[5]	Unknown	Unknown
Grain Handling and Milling	463	164
Iron and Steel[6]	981	507
Kraft (Sulfate) Pulp	73	30
Asphalt	15	12
Cement	110	30
Lime	11	15
Iron Foundries	317	108
Coal Cleaning	13	5
Petroleum Refineries	162	7
Petroleum Products and Storage	1,080	0
Sulfuric Acid Manufacture	176	41
Secondary Non-ferrous Metallurgy	62	22
Primary Non-ferrous Mettalurgy	321	127
Elemental Phosphorous and Phosphate Fertilizer	39	13
Rubber	2	1
Brick and Tile[7]	41	12
Varnish	1	1
Total	3,867	1,095

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[1] See Reference 3.

[2] Estimated for 298 selected metropolitan areas. The costs should not be considered as the total cost for achieving clean air, neither in the 298 areas nor in the nation.

[3] Total expense of purchasing and installing control equipment.

[4] Includes interest on funds, taxes where applicable, insurance premiums, depreciation, operating expense, and maintenance costs.

[5] See Reference 5.

[6] Does not include the cost to control coking emissions and blast furnace emissions.

[7] Cost to control fluoride (particulate and gaseous) emissions.

TABLE II

Air Pollution Emissions in the United States, 1968[1]

	Emission Rate (tons/year x 10^6)	Percent of Total
Transportation	90	42
Fuel consumption in stationary sources	45	21
INDUSTRIAL PROCESS	30	14
Solid waste disposal	11	5
Forest fires	17	8
Miscellaneous	21	10
	214	100

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[1] See Reference 4.

TABLE III

Estimated 1967 Particulate Emission Levels and Projected 1976 Particulate Emission Levels

Industrial Process Source[1]	Quantity of Emission (thousands of tons/year) 1967[2]	1976
Stone, Sand and Gravel[3]	4,600	Unknown
Grain Handling and Milling	2,952	59
Iron and Steel	1,490	89
Kraft (Sulfate) Pulp	633	119
Asphalt	522	40
Cement	400	24
Lime	344	28
Iron Foundries	217	31
Coal Cleaning	160	17
Petroleum Refineries	96	32
Sulfuric Acid	72	55
Secondary Non-ferrous Metallurgy	12	3
Primary Non-ferrous Metallurgy	10	2
Elemental Phosphorus and Phosphate Fertilizer	6	-
Rubber	1	1

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[1] See Reference 4.

[2] 1967 is used as the baseline year in conjunction with passage of the 1967 amendments to the Clean Air Act.

[3] See Reference 5. Also, year of listed emission rate unspecified.

TABLE IV

Estimated 1967 Gaseous Emission Levels and Projected 1976 Gaseous Emission Levels

Industrial Process Source[1]	Quantity of Emission (thousands of tons/year) 1967[2]	1976
Sulfur Dioxide:		
Primary Non-ferrous Metallurgy		
- Copper	2,940	294
- Zinc	263	16
- Lead	642	96
Petroleum Refineries	2,100	1,270
Sulfuric Acid Manufacture	750	129
Carbon Monoxide:		
Petroleum Refineries	6,200	331
Iron Foundries	3,200	205
Hydrocarbons:		
Petroleum Products and Storage	1,100	407
Petroleum Refineries	932	528
Varnish Manufacture	2	-

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[1] See Reference 4.

[2] 1967 is used as the baseline year in conjuction with passage of the 1967 amendments to the Clean Air Act.

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THE STATUS OF INSTRUMENTATION IN AIR POLLUTION CONTROL

By Robert E. Neligan
Acting Director, Division of Applied Technology
Bureau of Stationary Source Pollution Control
Air Pollution Control Office
Environmental Protection Agency
Research Triangle Park
North Carolina, U.S.A.

Introduction

Instrumentation used in air pollution control activities may be divided into three broad areas of activity: aerometric, that is the measurement of pollutants in the ambient air, source emission testing, the sampling or monitoring of emissions from stationary sources; and the measurement of pollutants from mobile source, automobiles and trucks.

Surveillance of air quality and the measurement of emissions from stationary sources has become an increasingly important function of any air pollution control agency. Initially the agency must determine the magnitude and scope of its air pollution problem, i.e., the extent to which air quality standards are being exceeded. This data and data collected through an emission inventory may then be used to fit a diffusion model, or used in proportional reduction or roll-back techniques. Either technique must be used to develop an effective emission control plan. Following the adoption of emission regulations, atmospheric surveillance is required to evaluate the progress toward the attainment of air quality goals. Additionally for those areas prone to the occurence of periods of high air pollution (episodes) surveillance becomes a vital part of any Emergency Action Plan.

Newly enacted Federal legislation in the United States requires that the Federal Government establish air quality standards for air pollutants. This has been accomplished for six pollutants: particulate matter, sulfur oxides, carbon monoxide, hydrocarbons, nitrogen oxides and oxidants. Now that these air quality standards have been established, each State must develop a state-wide plan to control these air pollutants to the level dictated by the air quality standard. The plan must include provisions for the establishment and operation of appropriate devices, methods, systems and procedures necessary to monitor, compile and analyze data on ambient air quality.

Thus, in the United States, air pollution control agencies at all levels of government are now conducting atmospheric surveillance activities to measure a wide range of particulate and gaseous pollutants. A survey of these activities (Table I) provides an estimation of the types of pollutants being measured as well as the number of devices presently in operation. This listing includes devices classified as static, mechanized and automatic. We define static devices as equipment that passively depends upon the natural movement of air currents to bring pollutants to the collector. Mechanized collection devices accumulate samples continuously or intermittently for subsequent laboratory analysis. Automatic devices are continuously operating sampler-analyzers that produce results directly in numerical or visual form or both. For the purposes of this report we will only consider continuous automatic instruments as most of these instruments use the same basic chemical technique as utilized by the mechanized devices.

Prior to discussing the status of aerometric technology, the objectives of air quality monitoring require elaboration. Recently, Morgan and Ozolins(2) presented four major objectives which are summarized as follows:

Documentation of Progress Toward Attainment of Air Quality Standards

The mechanism of controlling air pollution is through emission regulations imposed upon individual sources. No certainty exists that the adoption and enforcement of a set of emission regulations will result in a sufficient reduction in emissions to attain the air quality standards. Air quality monitoring provides the only means of ascertaining that sufficient progress is being made to achieve the air quality goals within the desired time period. Thus the air quality monitoring stations should be sufficient in numbers and geographical distribution to provide representative data for the entire region. In addition, where major point sources are likely to unduly affect a given area, it becomes necessary to locate monitoring stations which are primarily source-oriented.

Determination of Air Quality in Nonurban Areas

The primary emphasis in a program of emission control is to improve air quality in those areas where standards are not being met. Within most areas there are large areas of undeveloped land where ambient concentrations of most pollutants are well below levels specified in the standards. It is important that the quality of the air in these nonurban areas not be permitted to deteriorate to any significant degree. Of equal importance is the requirement to measure background concentrations of the air moving into a region. Thus some air sampling on the periphery (especially in the upwind direction) of the AQCR is necessary.

Information on Air Quality During Episodes

Control agencies are required to develop an action program to avoid the occurence of an air pollution episode. The heart of such a program is the emission-reduction plan. The enforcement of emission reductions must take into account the seriousness of the impending episode. Too little or too much of a reduction can result in a serious economic hardship upon the area. Therefore it is important to have immediate access to ambient concentrations data and follow a predetermined emission reduction plan consistent with the changing pattern of air quality. In order to provide the necessary data in "real time" to the control officer, most AQCR's will find it necessary to have at least one monitoring station equipped with continuous analyzers.

Improvement in the Reliability of Diffusion Models

Diffusion modeling has been found to be an effective tool in the management of air resources on a regional basis. Modeling can be used to supplement air quality measurement data to provide a better indication of the geographical distribution of air pollution. Additionally, and perhaps more importantly, modeling provides a means for evaluating the probable effectiveness of a set of control regulations prior to their actual adoption.

With the present state-of-the-art of diffusion modeling it is necessary to verify model estimates against actual air quality measurement data.

This diffusion model verification which is nothing more than fitting a linear regression model, requires air-monitoring data from a number of locations within the area. The success of recent attempts to utilize these models has for the most part been a function of the amount of measurement data available. Again, these activities have demonstrated the need for air quality monitoring throughout an area and not merely in one major municipality.

Continuous Aerometric Monitors--Gaseous Pollutants

Aerometric techniques in standard use today are based upon classical analytical techniques both chemical and physical. The following operational principles are commonly incorporated in continuous air monitoring instrumentation for gaseous pollutants.

Conductivity. The principle for conductometry, that is, electric conductance by soluble electrolytes, has had wide application as an analytical procedure. The electrical resistance of electrolytes in solution is inversely proportional to the conductivity, which in turn is proportional to the number of ions present and their mobilities. In dilute sample solutions, the measured conductivity can be directly related to the concentration of ionizable substance present. Sulfur dioxide has been measured by this procedure in continuous recording instrumentation for more than 15 years. The basic concept involved absorption of sulfur dioxide in de-ionized water (or a very dilute reagent) to produce an acid having conductance sufficient to be detected by a conductivity cell. Monitors employing de-ionized water as the reagent result in the formation of sulfurous acid (H_2SO_3). Interferences from carbon dioxide, salt, aerosols, acid mists and basic gases are common. Most sulfur dioxide analyzers use distilled or de-ionized water reagent modified by the addition of hydrogen peroxide and a small amount of sulfuric acid. This modified reagent results in the formation of sulfuric acid (H_2SO_4) upon reaction with sulfur dioxide. The acidic property of this modified reagent reduces the solubility of carbon dioxide gas within the reagent and minimizes this interference. Figure 1 displays, in schematic form, a conductivity-type analyzer. While instruments employing this principle have predominated the field in the past, instruments using either colorimetric or coulometric techniques have gained wide acceptance in the past few years due to their specificity.

Colorimetry. Colorimetry can be defined as a mode of analyses in which the quantity of a colored constituent is determined by measuring the relative amount of absorption of light passing through a solution of the desired constituent. The constituent may itself be colored and thus be determined directly, or it can be reacted with a substance to form a colored compound and determined indirectly.

Figure 2 is a block diagram of a typical colorimetric analyzer. As shown, an atmospheric sample is drawn into the air-reagent flow system, first entering the absorber or contactor where the desired constituent is reacted with the appropriate reagent. The air sample then passes to the upper portion of the absorber where it is separated from the reacted reagent, then passes through a flowmeter where the rate is indicated and controlled, thence to the air pump and discharged to the atmosphere. The reacted reagent passes from the bottom of the absorber into the continuous flow colorimeter where the optical absorbance of the solution is measured. In many cases a dual-flow colorimeter is employed whereby the absorbance of the unreacted reagent is initially measured. This measurement is used as a reference source.

This principle is commonly employed for the continuous measurement of three air pollutants: sulfur dioxide, using the West-Gaeke technique or a modification; nitrogen oxides by the Saltzman method; and oxidants using the neutral KI procedure.

Coulometry. Coulometry is a mode of quantitative analyses wherein the quantity of electrical current required to oxidize or reduce a desired constituent is measured. This measured quantity of current, expressed as coulombs, is proportional to the mass of the reacted material.

Coulometric titration cells for the continuous measurement of sulfur dioxide, oxidants, and nitrogen dioxide have been developed as a result of this principle.

One class of cells generally employed in continuous air monitoring are designed to respond to materials which are oxidized or reduced by halogens and/or halides as the case may be. Low concentration of the halogen and halide are maintained at equilibrium within the cell by means of competitive reactions at the cathode and anode. Upon introduction of a reactive material the halogen-halide equilibrium is shifted. The system is returned to its equilibrium conditions by means of a third electrode which regenerates the depleted species. The current required for this generation is measured and is directly proportional to the concentration of the depleted species, which in turn is proportional to the quantity of desired constituent. This mode of analyses can be classified as secondary coulometry usually employing a dynamic iodometric or bromimetric titration. These systems are designed to respond with a sensitivity in the lower part-per-billion range. Most commercial coulometric systems are made specific by the use of pre-filtration and/or chromatographic techniques that retain interfering compounds and permit passage of the desired constituents.

Another type of coulometric cell (Fig. 3) designed for ozone analyses, employs amperometric coulometry. Ozone is permitted to react with an iodide solution within the cell releasing iodine which depolarizes the cathode, thus permitting current flow which is proportional to the ozone concentration. By utilizing dynamic reagent and sample flows over the cathode and anode a continuous measurement is achieved. This type of coulometric monitor, like the first one described, is subject to interferences. Materials which undergo oxidation will appear as negative interferences; positive interferences with those which undergo reduction will be observed. In some cases such interferences can be overcome by the selection of chemically treated filters which are placed in the coming air stream.

Flame Photometry. Flame photometry is based on the measurement of the intensity of specific spectral lines resulting from quantum excitation and decay of elements by the heat of a flame. Volatile compounds are introduced into the flame by mixing them with the flammable gas or with the air supporting the flame. Non-volatile compounds are aspirated from a solution into the flame. The specific wave length of interest can be isolated by means of narrow band optical filters, diffraction gratings, or by means of a prism. The intensity of the specific wavelength can be quantified by means of a simple photo-tube or photo-multiplier tube and related electronics.

Recent development of flame photometric detectors (4,5) having a semi-specific response to volatile phosphorous and sulfur compounds has led to their use in continuous monitoring of gaseous sulfur compounds. This flame photometric device consists of a photo-multiplier tube viewing a region above the flame through narrow band optical filters. When sulfur compounds are introduced into the hydrogen rich flame they produce strong luminescence between 300 and 423 mu. A specificity ratio for sulfur to non-sulfur compounds of approximately 20,000 to 1 is achieved with a narrow band optical filter of 394 ± 5 mu. The detector response is a straight line relationship between 5 ppb and about 0.9 ppm on a log-log scale for sulfur compounds having a sulfur content in excess of 50% by weight. Positive interferences from other sulfur compounds are common while monitoring for SO_2, since the detector responds to all sulfur compounds. Discretion should be used in interpolating data obtained from this detector located in areas where other sulfur compounds exist.

Separation of part-per-billion levels of SO_2, H_2S, CS_2, and CH_3SH has recently become feasible through the use of chromatographic techniques(4). This mode of separation followed by flame photometric detection of the separated sulfur compounds has led to the development of a new type of semi-continuous monitor for sulfur containing gases which is specific and free from interferences.

Flame Ionization. Instrumentation employing flame ionization detectors, originally designed for gas chromatographic detection of organic compounds, has had wide application as a continuous monitor for hydrocarbons. The flame employed in this detector results from hydrogen gas combusted in air, with the subsequent formation of water vapor. The hydrogen is mixed with sample air which is introduced at a steady, controlled rate, before the two gases reach the burner tip. When an organic compound is present in the air stream, the flame produces ionized carbon atoms. These ions produce an ion flow between the flame and the collecting electrode suspended above the flame. This small current flow is amplified and measured. The response for hydrocarbon is linear and generally proportional to the weight percent of carbon present in the compound.

Advantages inherent in this detector are that it is: free from interferences resulting from inorganic gases, has a rapid response time, and has a low "noise background" level.

Recent investigations involving automated gas chromatographic(7) separation of the air sample into three fractions had led to the development of semi-continuous monitors for CO, CH_4, and total hydrocarbons. A gas chromatographic column provides separation of CO and CH_4 while flushing all other gases. The CH_4 is measured directly, while the CO fraction undergoes conversion to CH_4 in a controlled-temperature reactor containing a nickel catalyst and is subsequently measured by the flame ionization detector. The total hydrocarbon measurement is made directly without chromatographic separation. Total hydrocarbons less CH_4 provides an index of reactive hydrocarbons.

Nondispersive Infrared Photometry. The infrared absorption characteristics of several gases and vapors make possible their detection and analysis in continuous analyzers. For this purpose nondispersive infrared photometry rather than dispersive infrared spectrophotometry is used. Carbon monoxide as an air contaminant is uniquely suited to this method of analysis, and its absorportion characteristics and typical concentrations make possible direct sampling without pressurization.

A typical analyzer (Fig. 4) consists of a sampling system, an infrared source, sample and reference gas cells, detector, control unit and amplifier, and recorder. The reference cell contains a non-infrared absorbing gas while the sample cell is continuously flushed with the sample atmosphere. The detector consists of a two-compartment gas cell (both filled with carbon monoxide) separated by a diaphragm whose movement causes a change of electrical capacitance in an external circuit, and ultimately an amplified electrical signal which is suitable for input to a servo-type recorder.

During analyzer operation an optical chopper alternately exposes the reference cell and the sample cell to the infrared source. At the frequency imposed by the chopper a constant amount of infrared energy passes through the reference cell to one compartment of the detector cell while in varying amount of infrared energy, indirectly proportional to the carbon monoxide concentration in the sample cell, reaches the other detector-cell compartment. These unequal amounts of residual infrared energy reaching the two compartments of the detector cell are reflected by unequal transformation of infrared energy to heat and thence to mechanical energy in the form of detector gas expansion. This unequal expansion is the force which causes variation in detector-cell diaphragm movement and the resulting variation in the electrical signal described earlier.

Continuous Aerometric Monitors--Particulate Pollutants

The various approaches to particulate measurement include: high-volume and low-volume filtration sampling, measurement of individual particle density and optical characteristics, measurements of aerosol opacity and light scatter, and settling rates. Measurements of the allergenicity and infectivity of aerosols are also frequently made. However, this presentation will be limited to those devices in general use and considered to be continuous monitors.

Suspended Particulates. The recommended instrument for sampling large volumes of air for suspended particulate matter is the high-volume sampler. This sampler consists of a specially housed vacuum motor to which is attached a filter holder or adapter. It is evaluated and described by Robson and Foster[(8)]. While this device is not truly a continuous-automatic instrument, it is at present the only device that has received wide acceptance in the United States for the determination of total suspended particulates between 0.3 and 100 microns in size.

The adapter may be of one of two types: a circular 4 in.-diameter filter holder or a larger 8 by 10 in. rectangular adapter. The former is normally used in industrial-hygiene studies and will not be considered in this report. The latter adapter consists of two parts: the coneshaped stainless steel filter-support screen and an open rectangular face plate of case iron with a sponge-rubber gasket. In sampling, a filter is placed between the filter-support screen and the gasket face plate. When the adapter is screwed onto the blower unit, a circular rubber gasket is used to make an airtight seal.

Air drawn through the filter is measured with a "visa-float" flowmeter which must be calibrated. Samples are usually collected for about 24 hr., with a flowmeter reading at the beginning and end of each sampling period. The average rate of flow is then determined from a calibration chart for each instrument.

If desired, this device may be modified for continuous flow measurement and recording.

The modification consists of an orifice meter assembly attached to the exhaust end of a high-volume blower unit. A bellows-type pressure transducer is connected to the differential pressure tap of the orifice meter. The pressure developed across the orifice is continuously recorded on a circular chart and is converted to corrected airflow by means of appropriate calculations.

The filter material is generally glass-fiber although inert plastic materials are used in special samplings for certain metallic compounds. The filter with the collected particulate is routinely sent to the laboratory for not only the determination of the total particulate loading but for subsequent analysis by emission spectroscopy for the following metals: Cr, Cu, Fe, Pb, Mn, Ni, Sn, Ti, Zn, Sb, Bi, Cd, Co, Mo, Y. In addition analysis for sulfates, nitrates, and polynuclear hydrocarbons may be performed.

Soiling Particulates. The tape sampler measures the fine suspended particulates in the atmosphere. Air is drawn through a section of white filter paper, measuring one inch in diameter, at a pre-set rate (normally 0.5 cubic foot per minute) for a specific period of time. Generally, either one hour or two hour sampling periods have been used. The darkness of the spot on the tape is a function of the particulate matter in the air and consists of particles filtered out of the air. At the end of the sampling period, the tape advances automatically by means of a timing mechanism, placing a clean section of filter tape at the sampling port. The collected spot is automatically positioned under a photoelectric reflectance or transmission head which evaluates the density of the spot by measuring the light reflected from or transmitted through the spot to the cell. The greater the amount of particulate matter filtered out of the air, the darker the spot and the smaller the amount of light reflected or transmitted. The quantity of air sampled is expressed as lineal feet and the final result reported in either of two units of measurement, the reflectance unit density (RUD) or the coefficient of haze (COH), per 1000 lineal feet of air. The COH unit can be defined as that quantity of particulate matter which produces an optical density of 0.01 when measured by light transmission at 400 mu. The transmission of a clean filter is used as a reference and is set at 0.0 O.D. The RUD is the percentage reflectance obtained after passing 1000 lineal feet of air through a filter paper. The reflectance of a clean filter paper is set at 100% on the reflectance meter and is used as a reference.

Nephelometry. A common effect of particulate air pollution is the reduction of visibility. Small particles suspended in the air scatter light out of the line of vision, making distant objects appear less distinct. Visibility can be defined as that distance at which the difference in contrast between the background and the object being observed is too small to perceive.

Suspended particulates in the size range of 0.2 to 0.8 microns scatter rays of light in all directions. The amount of light scattered in any one direction depends on the size, quantity and composition of the particles. Therefore, to measure the amount of light lost by scattering, it is necessary to measure the scattering of all angles(10).

The air sample is drawn into the detection chamber where it is illuminated by a pulsed-flash lamp. The scattered light is measured over all scattering angles by means of mirrors and photo-multiplier tubes. The signal produced by the photo-multiplier is averaged and compared with a reference voltage from another phototube looking at the flash lamp. Calibration is performed by introducing clean filtered air and Freon-12 as reference sources. This device is designed to provide a reading of light scattering which can be defined as the reciprocal of the distance in which 63% of the light is lost from the source. The amount of light scattering is proportional to the mass concentration (ug/m^3) of suspended particulates if the mass and size distribution of the particles is assumed constant. Measurements of suspended particulates with this device affords the user a "real-time" continuous measurement.

Piezo-electric Sensor. This relatively new device delivers "real-time" measurements over a particle size range from 0.01--15.0 microns at concentrations up to 100,000 $\mu g/m^3$. It is quite versatile, applicable to monitoring the ambient atmosphere, stack effluents, and motor vehicle emissions.

The air to be tested is drawn through the unit by a small accessory vacuum pump. As the gas enters a teflon chamber, particles are electrostatically charged. The flow is directed over a piezo-electric sensor (S_1) and an electric field forces all of the particles into contact with the sensor. The adhering particles lower the resonant frequency of the sensor in direct proportion to their mass. A second piezo-electric sensor (S_2) mounted in the chamber is connected in a bridge circuit with S_1. It is not electrostatically charged, so particles do not adhere to it. It serves as a reference for S_1, that is, it is exposed to the same influences (temperature, pressure, etc.) as S_1, so any change in the relationship between the frequencies of the sensors will be caused only by particles accumulated on S_1. The output signal of the device is generated by mixing the frequencies of S_1 and S_2 so that the measuring sensor frequency is subtracted from the reference sensor frequency. The rate of change of this output frequency is directly proportional to the mass concentration of the particles. Mass concentration equals the change in frequency during a given period of time divided by a sensitivity constant. The instrument can be connected to a digital frequency counter display, a timer, and a printer, and its output can be transmitted from a remote station to a central location.

The Beta absorption tape monitor has also recently been used in the measurement of total suspended particulate. This monitor uses Beta radiation attenuation for the measurement technique. A sample of the particulate is deposited on a paper filter tape for a present period of time. The tape spot is then exposed to a stream of Beta particles from a small radioactive source. The Beta particles interact with the sample's electrons and the decrease in the Beta particle count as sensed by the detector is directly proportional to the number of electrons present in the sample. Thus the technique measures a parameter which is directly proportional to mass.

Current Developments in Continuous Aerometric Monitors

The most promising instrumentation developments for the measurement of air pollutants are based upon the application of well known spectroscopic quantitative-analytical methods in new configurations and combinations. All of these developments have the two main purposes: (a) the increase of instrument sensitivity in order to obtain sufficiently large signal-to-noise ratios for reliable and sufficiently accurate measurements of the commonly low air pollutant concentrations, and (b) the achievement of good interferences with the measurement of a particular pollutant species by other atmospheric or pollutant species and compounds. The physical methods available and the instrumental details required toward these aims have been exhaustively discussed and referenced in a recent NASA Report by Ludwig(10); therefore, here only a brief description of the basic principles involved will be given, together with representative and primising developments which are relevant for continuous and/or remote measurements of gaseous air pollutants. These developments can be subdivided into two major areas which deal with the application of spectroscopic and interferometric devices on the one hand and with the adaption of laser techniques on the other.

Spectroscopy. The main drawback of conventional spectroscopy--low sensitivity and low selectivity--can be overcome in principle by a method called correlation spectrometry. The basic concept utilized is the well-known technique of conventional quantitative spectroscopy of gas mixtures. For developmental applications several modifications of this principal have been considered in which either the spectrum is moved periodically across the exit slit array or vice versa, and in which the resulting alternating light signal is collected on a photodetector and processed electronically. Recently, a commercial instrument (Barringer Research, Ltd.) has become available. In this instrument, instead of an exit slit-array, a correlation mask is used which, for a portion of a spectral band of the gaseous species to be monitored, matches the spectral features both with respect to the wavelength and the relative intensity distrubitions of the lines (wavelength and intensity correlation)(11).

For aerial air quality assessments, for example, the instrument can be mounted in a vertically downward looking configuration in an aircraft and monitors sunlight reflected and scattered from the pollutant in the air layers underneath. The monitored species content in the atmosphere is determined in terms of an integrated optical depth in ppm-m (concentration times height of the line-of-sight in units of parts per million times meters) and, for example, can be converted to an average concentration by assuming a uniform species concentration over the height of the inversion layer. The calibration of the instrument is this application depends strongly on the local elevation of the sun and, in particular, by the local and temporal scattering properties of the atmosphere which is affected by the presence of aerosols and their distribution in the air-layers monitored. Thus far only NO_2 and SO_2 have been monitored successfully in spectral regions where negligible interferences by other gaseous pollutants occur, and the adaption of the instrument for field measurements of the pollutant species NO, CO, CO_2, and O_3 is still in the development stages.

Therefore, further research is required in the area of medium-to high-resolution spectroscopy of gaseous air pollutants and in the area of light scattering and absorption by aerosols in narrow and/or limited spectral regions which are of interest to correlation spectroscopy; at the same time, further development and test work is needed on instrument designs which would allow the simultaneous remote measurement of several pollutants also in cases where partial or complete overlapping of spectral bands occurs.

Laser Developments. The extensive application of absorption spectroscopy to pollutant analysis in the past has been limited by the degree of light-beam collimation and the amount of light energy available from ordinary light sources for medium- and long-path measurements through the atmosphere.

Hence, any development of light sources which will alleviate the problems of beam divergence and will increase the radiation energy available in spectral intervals where pollutants are strong absorbers, will allow significant improvement of pollutant measurement techniques. The most important new development in light sources is the laser (short for light amplification by stimulated emission of radiation) which inherently can provide light beams of very small beam divergence and high spectral intensity.

Typical optical arrangements for both laboratory and atmospheric transmission applications are shown schematically in Figure 5. It should be noted that for atmospheric transmission measurements, the collimation of laser beams is limited primarily by the diffraction effects of the optical system used and by the beam-spreading effects of atmospheric scattering and turbulence. Although at the present time no satisfactory experimental data are available about the propagation characteristics of narrow and wide cross-section laser beams as a function of the beam-interfering atmospheric structure, content and motion, it seems reasonable to expect that atmospheric beam spreading will not seriously limit the application of low power and continuous laser sources to remote pollution measurements by aerial, medium- and long-distance methods.

At the present time a multitude of gas lasers are commercially available and more are in various development stages. They can emit at several or many wavelengths in the near ultra-violet, and visible and the infrared regions of the spectrum by stimulated emission of gases like neon (Ne), argon (Ar), iodine (I_2), carbon dioxide (CO_2), carbon monoxide (CO), nitric oxide (NO), nitrous oxide (N_2O) and others. Furthermore, various successful techniques have been introduced by which the wavelengths for peak power emission of multi-line gas lasers can be changed or shifted. For example, refracting prisms and diffraction gratings have been introduced into the optical cavities of noble gas and nitrogen as well as carbon dioxide lasers and are becoming commercially available standard accessories.

Recently a new method for the wavelength-shifting has been developed for the carbon dioxide and the recently discovered iodine laser; in a separate compartment of the optical cavity a special gas sample is introduced by which the laser output energy as a function of wavelength is changed from different pressures of the gas sample. (See Fig. 6). In particular, it has been shown at CO_2-lasers and I_2-lasers can be made specific by this method and by the introduction of isotopic laser gases for five major pollutants: ethylene, ozone, carbon monoxide, nitric oxide and sulfur dioxide.

In addition to these five pollutants, many others can be detected in principle by the absorption of laser radiation, and the sensitivity for practical measurements will depend on the strength of the useful pollutant absorption lines, the intensities of the useful laser lines, the stability of the laser output energy, the beam fluctuations caused by atmospheric turbulence and the refinements built into the electronics of the detector system. Representative estimated sensitivities for infrared measurements of some gaseous pollutants by different gas lasers are shown in Table II.

The rapid evolving new physical methods of correlation and laser spectroscopy for the remote and the local monitoring of air pollutants by their very nature possess inherently the very promising potential for instrumental simplicity, good durability and reliability, high sensitivity, easy adaptability to automation and electronic interfacing, and excellent mobility when compared with the presently common techniques employed by local monitoring stations. Although their application to measurements in the field is still in its infancy, it appears eminently reasonable to expect that these methods can be developed to a practical degree of perfection which will make them superior to any other procedures for accurate and widespread air quality monitoring.

Accurate, specific and flexible-monitoring techniques for large areas of population, industry and farmlands, as well as for particular local applications, are mandatory for both the realistic and rational control of air pollutants and the realistic and rational setting of sound air quality standards. The superiority of these over other methods is further amplified by the fact that they can be adapted easily to a vast amount of different pollutant species while leaving unchanged the basic instrumentation principles and concepts. Hence, one can envision the emergence of new "streamlined" and standardized pollutant-monitoring systems for large areas. The systems would be based upon a relatively small number of similar or even equal basic instruments with relatively cheap interchangeable accessories. These could be used in stationary or mobile modes of operation for the measurement of many more air pollutants than is possible at the present time by the vast variety of individual monitoring instruments which are commercially available for the measurement of a relatively small number of pollutants. For example, the price of 100 new and fully automatized air analyzers for the measurement of five gaseous pollutants by presently common techniques is about $2.5 million and requires an additional amount of at least about $250 thousand per year for operating costs. These figures do not include salaries of highly qualified and diversified technicians and staff members. Thus an equal number of correlation spectrometers for local and remote, short- and medium-distance measurements of two or three gaseous pollutants would cost about $1.2 million to $1.5 million and would presumably require a much lower yearly operating budget. Similar or much lower price ranges may be anticipated in the not too distant future for local, short- and medium-distance analyzers which operate on the basis of frequency shifted, low-power CO_2- and I_2-lasers. Low-power, interchangeable helium-neon laser tubes are advertised now for less than $50.

Stationary Source Measurements

Stationary source emissions monitoring has been virtually ignored until the past several years. With the passage of the Clean Air Act Amendments of 1970 new emphasis has been placed on the development of such instrumentation. The Act requires the establishment of performance standards for stationary sources and the monitoring of stationary source emissions.

The monitoring of particulate emissions in the past has been attempted through the use of transmissiometers or smoke density meter and tape samplers which exposed a white paper surface to the effluent and measured the decrease in light reflectivity. The major problem with both techniques is that they measure a change in light intensity. Unfortunately, this intensity change is affected by particulate size, number, shape, color, index of refraction, chemical composition and in some cases deposition characteristics.

Numerous attempts have been made to produce transmissometers which will accurately reflect the mass of particles. The "best" correlation found thus far is a unit which was shown to be in error by no more than 200 percent under typical conditions.

The techniques which appear to be viable at this time are Beta absorption with semi-continuous paper-tape sampling and a piezoelectric quartz crystal microbalance with electrostatic precipitation or cyclone collectors.

The Beta radiation attenuation technique uses an extracted sample which is deposited on a paper filter tape for a preset period of time. The tape is indexed into a stream of Beta particles from a small radioactive source. As some of the Beta particles interact with the sample's electrons, the decrease in the Beta particle count as sensed by the detector is directly proportional to the number of electrons present in the sample. Therefore, the technique measures a parameter which is directly proportional to mass. Hence the identification of this technique as a potential usable mass monitor. Problems to be overcome are to produce a higher counting rate and therefore a more real-time monitor and improvement in reproducibility.

The application of the piezoelectric quartz microbalance is relatively recent. The basic principle uses the piezoelectric effect to make a small quartz crystal vibrate in a horizontal plane. The frequency of this vibration is very constant and is determined mainly by the size or mass of the crystal and to a lesser extent by the temperature. The temperature effects can be minimized and compensated by the use of an identical crystal in a bridge circuit. The particles are deposited on the sample crystal by electrostatic precipitation, cyclone, impactor, etc., for a period of time. The increased mass of the crystal plus particles lowers the natural vibration frequency. This change in frequency is directly proportional to the mass of particles on the crystal. The sampling and analysis times are variable depending on the amount of particulate matter being sampled, and the accuracy desired. High accuracy may require a longer frequency counting period. Very low particulate loadings require longer sampling periods to collect a measurable amount of particulate. A typical monitor sampling at 1 liter/minute at 0.05 gr/SCF can collect enough matter for analysis in under 1 second.

Potential problems in this device at this time are concerned with larger particles not remaining firmly seated on the crystal during each vibration, problems encountered in precipitating the particles onto the crystal, and problems of cleaning the crystal after the measurement. One manufacturer uses a light adhesive coating to make larger particles adhere to the crystal better but this will probably necessitate more frequent cleaning. The usual electrostatic precipitation problems can be countered by the use of impactors or cyclones but at the sacrifice in ability to measure the smaller particles. The PQ device has not been extensively tested in a stack environment at this time.

The emission monitoring for sulfur dioxide is somewhat advanced over that of particulates. The continuous monitoring for sulfur dioxide has been accomplished using ultraviolet detection principles. There is presently available on the commercial market an instrument which has operated satisfactorily for over a year on a large coal-fired boiler. In addition, such monitors have been used to measure sulfur dioxide emissions from sulfuric acid plants. In both instances there were some initial problems to overcome with sampling systems and sample pretreatment. However, these difficulties have been solved and the units are reportedly operating satisfactorily.

Other measurement techniques have been employed such as the galvanic or fuel cell and electroanalytic methods. Preliminary reports on the fuel cell device indicate that there are problems still to be resolved with this technique such as a short-life time (30 days) for the sensing element and random drifting of the unit.

Instruments utilizing the non-dispersive infrared principle have been and are being used to some extent. The major problem with this procedure is that the stack gas sample must be conditioned to remove water vapor (100 ppm H_2O vapor = 1 ppm SO_2). Such conditioning also removes approximately 5 percent of the sulfur dioxide in the sample stream. This problem has been partially overcome by the close control of the condensation temperature.

Monitoring of oxides of nitrogen has been accomplished by the use of ultraviolet instrumentation. Since nitric oxide is essentially transparent in the visible and ultraviolet, quantitative conversion to nitrogen dioxide is required for measurement by the instrument. This conversion is achieved by reacting the sample containing nitric oxide with oxygen at elevated pressure. The reaction is both rapid and reproducible. Normal operation allows for the instrument to scan the incoming gas stream for its nitrogen dioxide content. The time interval for this scan is 1 to 3 minutes. The incoming gas stream is then contained in the sample cell and pressured to approximately 5 atmospheres with oxygen. The nitric oxide is thereby oxidized to nitrogen dioxide and a reading made. Time sequence for this operation is usually 5 to 7 minutes. By this alternate operational mode the gas stream concentrations of both nitric oxide and nitrogen dioxide are obtained. This instrumental technique has been used in the monitoring of nitric acid plant effluents as well as combustion sources.

Galvanic or fuel cell technology has also been used for the monitoring of oxides of nitrogen in stack gases.

Presently there are other chemical and physical techniques being utilized to monitor diverse pollutants from stationary sources. Among these one should include gas chromotography followed by electrometric titration or microcoulometric detection for the measurement of hydrogen sulfide, sulfur dioxide and various organic sulfur compounds from various sources within Kraft pulp mills. The fluoride-specific ion electrode has been reported to have been used to monitor fluorides in stack gases.

Mobile Source Measurements

The measurement of pollutants from motor vehicles has centered around three pollutants: hydrocarbon, carbon monoxide and oxides of nitrogen. As these pollutants vary in both concentration and rate of flow as a function of engine speed and load, monitoring instrumentation or sample collection methods have had to be designed to meet these circumstances.

In the past, in order to determine the true mass emissions from a motor vehicle, it has been operated on a dynamometer using a driving cycle which simulated actual road use. The instrumentation used to follow this sequence of events has been connected directly to the exhaust pipe of the vehicle and therefore a short-time response was required to monitor the rapidly changing concentrations.

Non-dispersive infrared instruments were utilized to determine the carbon monoxide and hydrocarbon concentrations. The hydrocarbon analyzer was sensitized with n-hexane. Hence the analyzer responded more strongly to paraffinic hydrocarbons, less to olefinic and least to aromatic and therefore was strongly dependent upon fuel composition.

Under new Federal standards and regulations promulgated for 1972 model year vehicles, the measurement of hydrocarbon emissions will be accomplished using the flame ionization detection technique. In addition, the driving cycle has been changed to more truly represent driving patterns in major metropolitan areas and the exhaust gases are collected in a large plastic bag after dilution with air. Carbon monoxide is still measured by the non-dispersive infrared method.

The flame ionization method gives a more accurate measurement of the hydrocarbon emissions as it will detect any organic molecule that has a carbon-carbon or carbon-hydrogen bond. It is therefore not as fuel sensitive as the infrared method.

Recently Federal motor vehicle standards have been proposed for nitrogen oxides. The proposed method of measurement utilizes the chemiluminescence technique. Basically the instrument operates on the principle that nitric oxide reacts with ozone to give nitrogen dioxide and oxygen. Approximately 10 percent of the nitrogen dioxide is electronically excited to higher energy levels. The transition of excited nitrogen dioxide to the ground state yields a detectable light emission at low pressure. The intensity of this emission is proportional to the mass flow rate of nitric oxide into the reactor. The light emission can be measured utilizing a photomultiplier tube and associated electronics.

As the standard is for nitrogen oxides, any nitrogen dioxide present in the exhaust gas must be converted to nitric oxide. This is accomplished by utilizing a nitrogen dioxide converter which is connected into the inlet gas stream. The conversion is accomplished by thermal decomposition of nitrogen dioxide to nitric oxide and oxygen.

Substances which cause positive interferences with this method are ammonia, low molecular weight amines, nitrates nitrites, nitriles and nitro compounds.

Fuel cell technology has also been used in instrumentation for nitrogen oxides measurements. It is reported that such devices have proved to be reliable in service. Interferences from side-chain aromatic compounds have also been cited.

A comprehensive bibliography of recent papers, extending over the entire field of pollutant measurement activities, is issued biannually in the publication Analytical Chemistry. The reader is referred to the most recent publication in April, 1971.

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Table I

Estimated Number of Air Surveillance Devices in Routine Operation in the United States(1)
(June, 1970)

Pollutant and method	Nonfederal agencies	APCO	Total
	Static		
Gases: sulfation rate	2,933	214	3,147
Particulates:			
Settleable (dustfall)	3,220		3,220
Windblown (sticky paper)	897		897
	Mechanized		
Gases:			
Aldehydes	271		271
Ammonia	262		262
Nitrogen dioxide	362	200	562
Oxidants	395		395
Mercury		50	50
Sulfur dioxide	515	200	715
Hydrogen sulfide	153		153
Particulates:			
Suspended (Hi-Vol)	2,074	293	2,367
Membrane filter		55	55
Cascade-fractional		15	15
Soiling (spot tape)	461	10	471
	Automatic		
Gases:			
Aldehyde	16		16
Carbon monoxide	218	10	228
Carbon dioxide	10		10
Hydrogen sulfide	83		83
Nitric oxide	117	17	134
Nitrogen dioxide	189	17	206
Oxidants	122	14	136
Sulfur dioxide	235	44	279
Particulates:			
Soiling (automatic tape)	367	7	374
Total	12,900	1,146	14,046

Table II

Representative Details for the Detection of Some Pollutants by Laser Radiation in the Infrared(10)

Pollutant	Source	Location or ir band centers (u)	Laser line to be used	Concentration in parts per million to give 5% signal change over a 1 km path (estimated)	Remarks
CH_4	Marsh gas	3.35, 7.7	He-Ne-3.39	0.03	Naturally in the air.
C_2H_2	Auto exhaust combustion	13.7	Ne?	...	Very strong absorption.
C_2H_4	Auto exhaust combustion	10.52	CO_2-10.53	0.02	Distinctive spectrum, strong Q-branch.
C_4H_{10}	Many, including auto exhaust	3.4	I_2-3.43	0.05	C-H band is a measure of total organics.
PAN	Atmospheric photochemistry	5.4, 7.8	He-Ne?	0.05	Other bands are available.
NO	Auto exhaust combustion	5.3	I_2-5.5	0.5	Iodine line will penetrate humid atmosphere.
NO_2	Auto exhaust combustion	3.4, 6.2	Rare gas?	...	A difficult case due to water interference.
CO	Auto exhaust combustion	4.7	I_2-4.86	2.0	Some other laser line could make detection more sensitive.
O_2	Atmospheric photochemistry	9.6	CO_2-9.5	0.05	One of the simplest cases.

Table II (continued)

Representative Details for the Detection of Some Pollutants by Laser Radiation in the Infrared(10)

Pollutant	Source	Location of ir band centers ($_u$)	Laser line to be used	Concentration in parts per million to give 5% signal change over a 1 km path (estimated)	Remarks
SO_2	Burning of sulfur-cont. fuels	7.3, 8.7, 18.5	Ne-7.4	0.03	Needs work to find better laser line.
NH_3	Organic wastes, industry	10.5	CO_2-10.7	0.02	Very strong lines at about 10.3 and 10.7.
H_2S	Industry	2.6, 7.7	Kr?	...	
HF	Burning of plastics	2.3	Kr?	...	
HC_1	Burning of plastics	3.6	Xe?	...	
D_2O	Atomic energy installations	3.7	Xe	...	

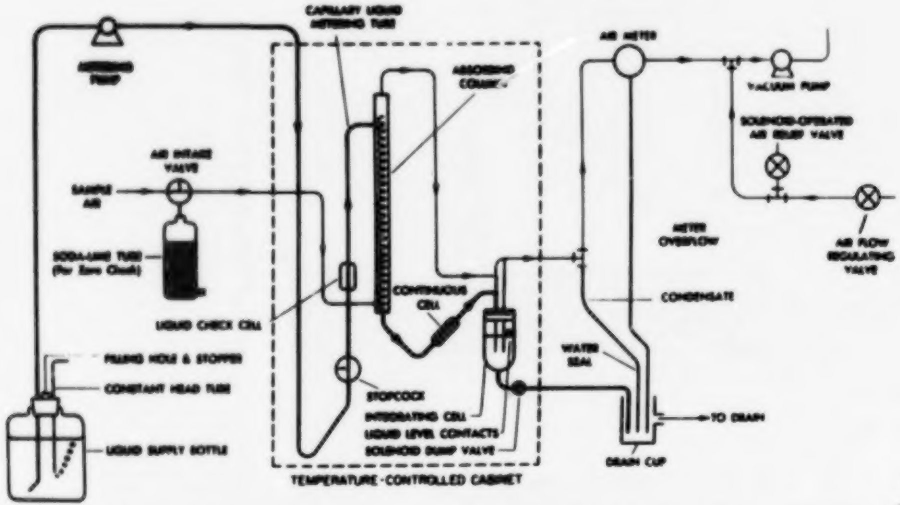
CAPILLARY LIQUID METERING TUBE
METERING PUMP
ABSORBING COLUMN
AIR METER
VACUUM PUMP
SOLENOID-OPERATED AIR RELIEF VALVE
AIR INTAKE VALVE
SAMPLE AIR
METER OVERFLOW
AIR FLOW REGULATING VALVE
SODA-LIME TUBE (For Zero Check)
CONTINUOUS CELL
CONDENSATE
LIQUID CHECK CELL
WATER SEAL
FILLING HOLE & STOPPER
CONSTANT HEAD TUBE
STOPCOCK
INTEGRATING CELL
TO DRAIN
LIQUID LEVEL CONTACTS
LIQUID SUPPLY BOTTLE
SOLENOID DUMP VALVE
DRAIN CUP
TEMPERATURE-CONTROLLED CABINET

Figure 1: Schematic Diagram of a Conductivity-Type Monitor(3)

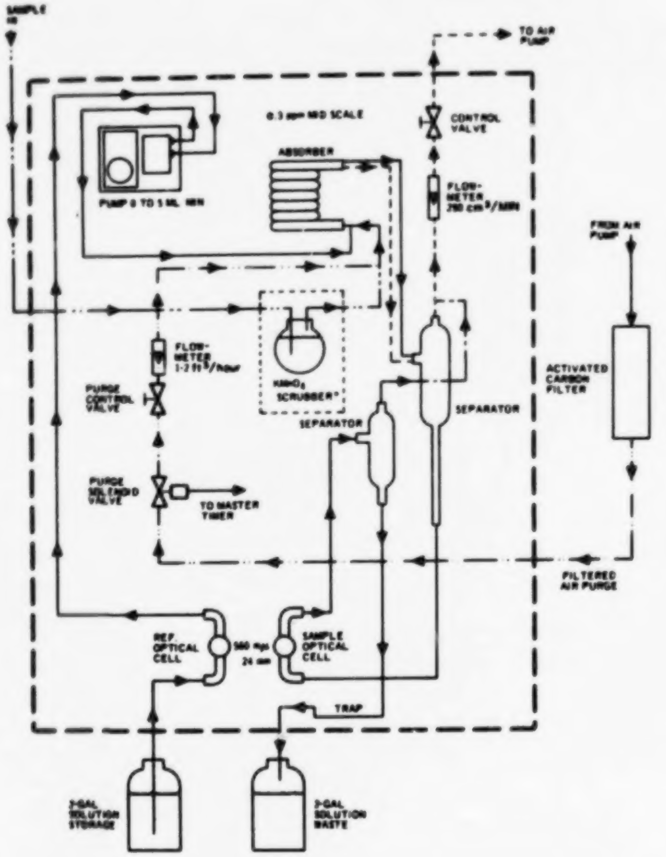
SAMPLE IN
TO AIR PUMP
0-3 ppm NO SCALE
CONTROL VALVE
ABSORBER
PUMP 0 TO 5 ML MIN
FLOW-METER 250 cm³/MIN
FROM AIR PUMP
FLOW-METER 1-2 ft³/hour
$KMnO_4$ SCRUBBER*
ACTIVATED CARBON FILTER
PURGE CONTROL VALVE
SEPARATOR
SEPARATOR
PURGE SOLENOID VALVE
TO MASTER TIMER
FILTERED AIR PURGE
REF. OPTICAL CELL
560 mμ 24 mm
SAMPLE OPTICAL CELL
TRAP
3-GAL SOLUTION STORAGE
3-GAL SOLUTION WASTE

Figure 2: Schematic Diagram of a Colorimetric-Type Monitor(3)

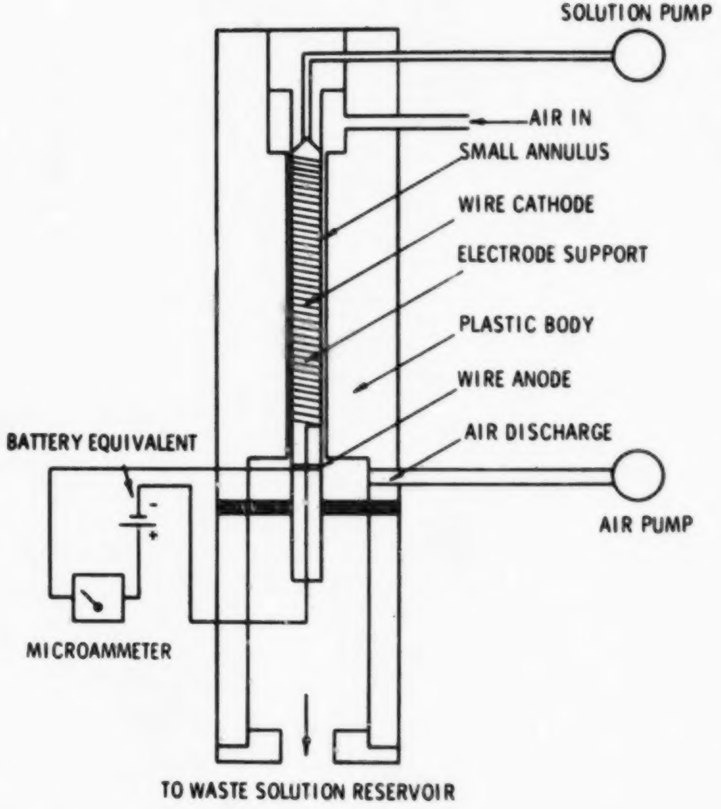
SOLUTION PUMP
AIR IN
SMALL ANNULUS
WIRE CATHODE
ELECTRODE SUPPORT
PLASTIC BODY
WIRE ANODE
AIR DISCHARGE
AIR PUMP
BATTERY EQUIVALENT
-
+
MICROAMMETER
TO WASTE SOLUTION RESERVOIR

Figure 3: Schematic Diagram of Amperometric Coulometry-Type Monitor(3)

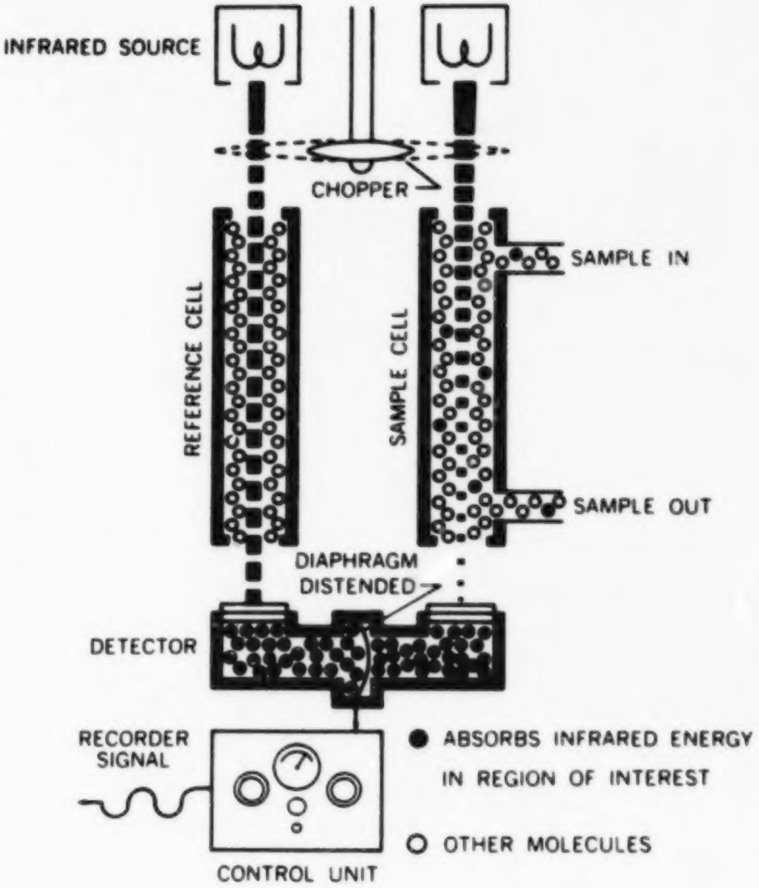
INFRARED SOURCE
CHOPPER
REFERENCE CELL
SAMPLE CELL
SAMPLE IN
SAMPLE OUT
DIAPHRAGM DISTENDED
DETECTOR
RECORDER SIGNAL
CONTROL UNIT
● ABSORBS INFRARED ENERGY IN REGION OF INTEREST
○ OTHER MOLECULES

Figure 4: Schematic Diagram of Nondispersive Infrared Type Monitor(3)

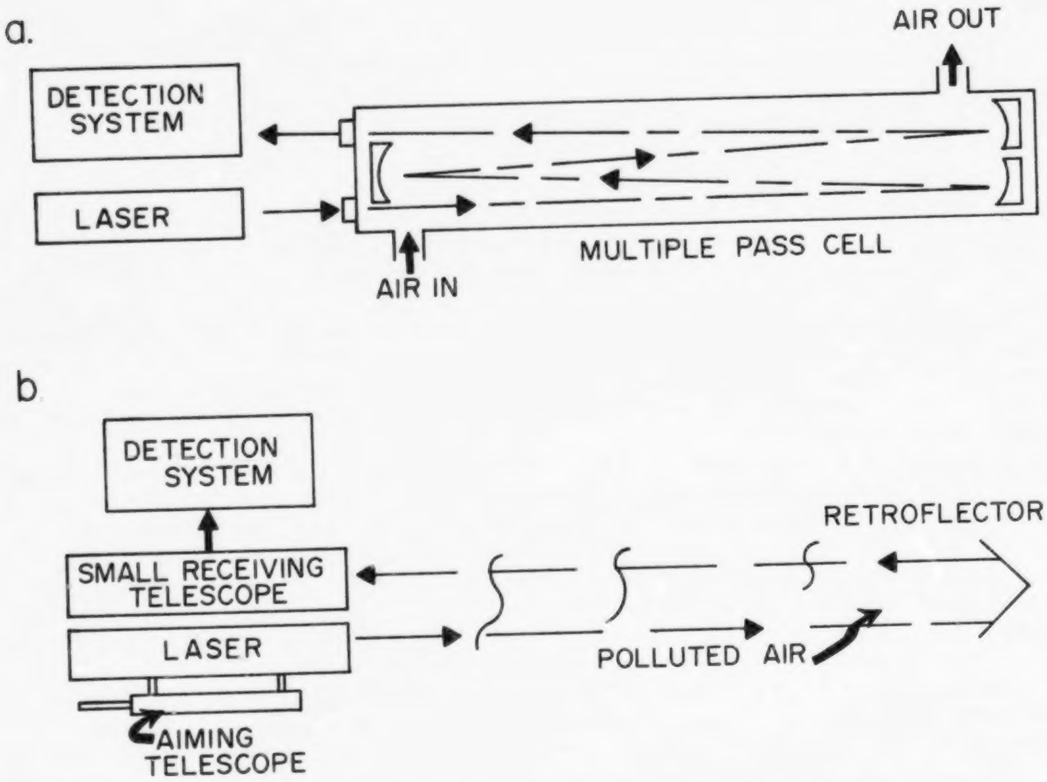
a.
AIR OUT
DETECTION SYSTEM
LASER
MULTIPLE PASS CELL
AIR IN
b
DETECTION SYSTEM
RETROFLECTOR
SMALL RECEIVING TELESCOPE
LASER
POLLUTED AIR
AIMING TELESCOPE

Figure 5: Typical Optical Arrangements for Pollutant Absorption Measurements by Lasers: a. Folded Laser Beam, b. Retroreflected Laser Beam

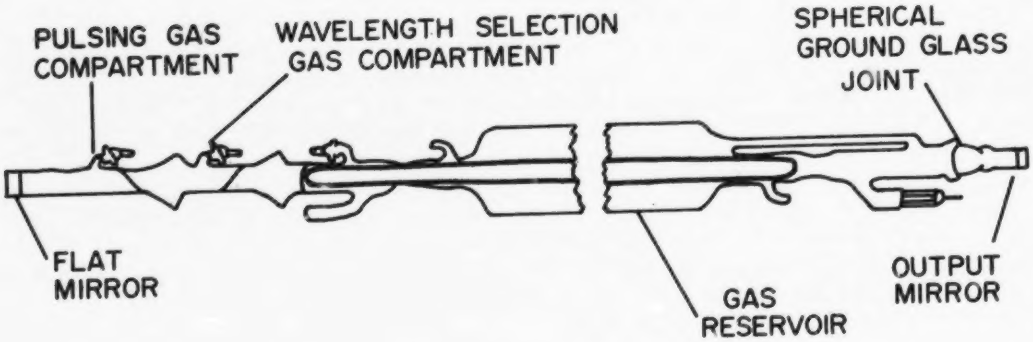
PULSING GAS COMPARTMENT
WAVELENGTH SELECTION GAS COMPARTMENT
SPHERICAL GROUND GLASS JOINT
FLAT MIRROR
GAS RESERVOIR
OUTPUT MIRROR

Figure 6: Laser Light Source for Specific Pollutant Detection

THE EFFORT FOR CLEAN AIR IN THE NETHERLANDS

By N.J.A. Groen
Chief Public Health Officer
State Inspectorate for Public Health
Leidschendam, The Netherlands

It is said that the late King Edward I, who was reigning over England at the end of the thirteenth century, received a formal complaint concerning air pollution. The complaint was forwarded by a number of noblemen, accusing their subjects of using coal fires which caused smoke and soot and defaced their properties.

Although the King died in 1308, we--as fighters for clean air-- consider him as immortal because, one year before his death, he issued the first decree against air pollution; in fact a decree against the use of coal as a fuel in London. There were successive sanctions in his decree: first of all a fine and, for recidivists, destroying of their furnaces. Although it may not have been in these particular sanctions, it is well known that in the same era a man was tortured in public because the smoke from the chimney of his house heavily contaiminated the environment.

Since John Evelyn, walking in the Royal Place at Whitehall in 1665, described a tremendous smoke invading the Court, we can conclude that things seem not to have improved much during the succeeding four centuries.

Evelyn suggested a quite modern solution: the creation of green spaces and a better town planning. However he was ahead of his time; it took a couple of centuries more before the Clean Air Act came into force in the United Kingdom.

Air pollution in that period was not restricted to England. In The Netherlands, the City of Haarlem issued a decree in 1608, prohibiting the use of English and Scottish coal by breweries because of the smoke coming from this kind of fuel. The issue of this decree possibly had a political background since the bleachers in the town polluted the water that the breweries needed for preparing beer, and for that reason, some years before, bleaching had been prohibited in certain areas. Although the complaints of the brewers and the revenge of the bleachers perhaps didn't result from pure reason, they lead to an improvement of the water and air situation in that region.

In this respect we must confess that this kind of reasoning has been for too long a leading principle in the battle against environmental pollution. On the other hand we must be aware that success in this battle is closely connected with progress in science, and the availability of better means for pollution prevention. This holds, as far as I can see, for the whole world and for Holland as well.

General

The Netherlands is a relatively small, but very densely populated country, especially in the western part. The population is still growing. More than 55% of the population lives in the big cities; only 22% lives in small villages. The concentration of industry in some areas has grown considerably, especially since the second World War.

Rotterdam is considered to be the biggest port of the world, with a turnover of more than 160 million tons per year. Near Rotterdam are five big oil refineries with a total capacity of 62 million tons per year.

The Netherlands is a flat country without important mountains or valleys. Our highest hill, at the point where Germany, Belgium and Holland meet, reaches 321 meters. The climate is a moderate sea climate. Wind is, on the average, rather strong and variable. Near the coast, where most of industry is situated, it is stronger than near the eastern border. However there are periods of several days with very low wind velocities and especially in wintertime, with fog.

Sources of Air Pollution

The oldest source of man-made air pollution is the use of fuels for heating. Before the second World War the fuel normally used for domestic heating was, in contrast with some other countries, a good quality of anthracite or coke, burned in closed furnaces. The use of open fires or bituminous coal was rare. After the war the use of oil and kerosene emerged as a more convenient and cleaner way of heating. However, during the last five years the use of natural gas, found in this country in enormous quantity and almost without sulphur, has increased very rapidly for domestic heating. The government's aim is to completely change to natural gas for domestic heating in our cities in a period of approximately five years. In presenting a new law against air pollution to the parliament in September 1968, the government noted that the increasing availability of natural gas gave reason to expect a decrease of that part of the nation's air pollution caused by domestic heating. Since that time the concentration of sulphur dioxide in our cities has, in fact, shown a decrease, and it may be expected that this decrease will continue.

There are, in certain areas, e.g. in the area between Rotterdam and The Hague, an important number of glasshouses for growing fruits and vegetables, which have been, until now, mainly heated by high sulphur content fuel oil. With significant financial aid from the government and other official institutes, the way is being cleared to use natural gas instead of oil for this purpose. It is expected that within three years the majority of glasshouses will be heated by gas. This change will undoubtedly lead to an important decrease of sulphur dioxide concentration in cities like The Hague, Delft and Rotterdam.

Industry and power plants are still using coal, as well as natural gas and oil. Here, too, there is an increasing use of gas. It is estimated that in 1970, the total national energy supply was 11% by solid fuel, 65% by liquid fuel and 24% by gas.

The availability of natural gas has caused another improvement. Gasworks, present in most larger cities, with their dust and bad odors have completely disappeared.

Transportation is the second and newer cause of air pollution in Holland. Our railways exclusively use electric or diesel electric drive, causing almost no air pollution. However the number of motor cars is increasing rapidly. It now amounts to nearly 3 million and by 1975, that number will rise to 5 million. Though we can be proud of our--single--motorcar industry, it is clear that we are not in a position to make regulations for cars from other countries. Therefore restrictions for new cars are worked out jointly with other European countries; and will be put in force before the end of this year. The maximum carbon monoxide content during idling will be fixed at 4.5%; and the total amount of carbon monoxide and hydrocarbons, emitted during a European driving cycle, will be restricted.

Industry is the third source of air pollution in our country and is developing very rapidly. The chemical and petrochemical industry especially is increasing, not only in size but also in diversity. Every industry needs a license before coming into operation. This license, until now given by municipal authorities, is granted under certain conditions. Lack of staff in most of our municipaities during past years has underlined the necessity for better supervision by central governmental authorities. Working along these lines, it has been possible to restrict air pollution caused by new industries. Our new law, accepted by Parliament during the past year, and probably coming into force this year, will improve control of industrial air pollution.

Aspects of Air Pollution

As measured by the usual parameters and expressed as sulphur dioxide and smoke, air pollution in The Netherlands is relatively moderate. Smoke concentrations are far below those in the United Kingdom, measured by the same method. Average sulphur dioxide concentrations during the winter months in Rotterdam are below 300 $\mu g\ SO_2/m^3$. These concentrations are still decreasing, but occasionally rather high concentrations occur, and there have been 14 days with an average concentration of 500 $\mu g/SO_2/m^3$ or more during the winter of 1966/67. The concentrations of polynuclear hydrocarbons are very small, much lower than those found in other European countries: the average concentration of 3.4.-benzpyrene in Rotterdam in the winter of 1967 was only 5 $\mu g/1000\ m^3$.

Adverse effects of air pollution on plants and vegetation are frequently observed, but normally are restricted to a small area. Damage by sulphur dioxide, hydrogen fluoride, photochemical smog, ethylene and nitrogen oxides, have been observed. A number of investingations in this field have been carried out the Institute for Plant-Disease Research (Instituut voor Plantenzicktekundig Onderzoek, "IPO-TNO") at Wageningen.

Special investigations concerning the influence of air pollution on health have not given significant results. A careful study by Dr. K. Biersteker on health effects during a period of heavy air pollution in December 1962 in Rotterdam indicated a small increase in mortality, but this increase was not significant, and its relation with air pollution could not be proven. Another investigation, comparing health conditions of school children in a polluted and a non-polluted part of Rotterdam, gave results indicating differences, probably more due to different social conditions than to air pollution. An important investigation, concerning the incidence of chronic non-specific respiratory diseases in a polluted and a non-polluted part of the dountry, did not show any significant influence of air pollution. The polluted region chosen was the town of Vlaardingen, in the Rotterdam area. The non-polluted area chosen was a village (Vlagtwedde) and a small town (Meppel), both in the northeast of the country.

Nevertheless we have had periods of increased air pollution that have caused much public concern. Some of these periods were clearly due to accidents in industry; others by a combination of high emission from one or more industries and unfavorable meteorological conditions. For the evaluation of such situations--and for normal situations as well--we receive indispensable help from the Royal Netherlands Meteriological Institute (Koninklijk Nederlands Meteorologisch Instituut--KNMI) at De Bildt, near Utrecht.

There is increasing public concern about air pollution in our country and a fear of the influence of air and water pollution on health. The number of complaints about bad odors or other observable effects of air pollution is increasing. This does not prove that malodors occur more frequently than some years ago, but the population is more aware of these unpleasant situations and no longer accepts situations that would have been accepted 10 or 15 years ago without complaint.

This attitude may be helpful for those that have to control air pollution, but it is not without certain disadvantages. It may hamper a well balanced policy that on a long term basis will give best results.

Law Against Air Pollution

As already noted, a special act against air pollution has been accepted by the Parliament and is now partly in force. As the result of this law the government is authorized to promulgate regulations to control air pollution caused by apparatuses, fuels or other activities. Among the apparatuses that can be regulated are large and small installations in industry, motor vehicles, furnaces for domestic heating, airplanes and domestic chimneys.

One of the first regulations applicable to apparatus will probably be the obligation to have new types of motor vehicles tested. Possibilities in the fuel sector are the prohibition of the use of certain fuels, for instance those with a high sulphur content, perhaps limted to more polluted areas in the country. On the other hand we can envision limitation on the composition of fuel for motor vehicles. However, for the time being, we are not yet ready to do all these things and must wait for the future to learn how to implement this new act.

The Inspectorate of Environmental Hygiene was established in 1962 as an independent part of the organization (under the Minister for Social Affairs and Public Health) charged with the supervision on public health (Staatstoezicht op de Volksgezondheid). This inspectorate has an important part in the preparation of the above noted regulations as well as in the supervision and execution of the entire law.

Until the passage of this law, when an industry needed a license, it was granted by the municipal authorities. Both the regional officer for environmental hygiene and the regional labor inspector were asked for advice.

Under the new law the provincial authorities will have the responsibility for giving licenses for those industries that have an important air pollution potential, since significant air pollution doesn't stop at the borders of license-giving municipalities. Therefore, granting the license by the province can give better protection against air pollution to surrounding municipalities.

Under the new law, the regional publich health officers and labor inspectors will still advise the provincial authorities. This gives an essential role to officers who are experts on environmental and industrial hygiene We expect that in general their advice will be followed by the licensing authorities, both because of their competence, but also because, if the advice is not followed, there may be an appeal to the Crown. The Council of State, acting for the Crown, is in fact the ultimate authority with respect to the granting of licenses and the restrictions applied.

Not all licensed industries are of equal importance. In the present transition period--before the enforcement of the new act--a number of smaller industrial pollution sources can remain under the existing legal rules. For these smaller sources a number of general directives, based on practical experience, will be framed. These directives may apply to classes of apparatus or to special industrial groups. Under the new act such directives will attain official status.

The attainment of an official status also applies to air quality and emission standards which, until now, have not been official. Such standards will be handled very carefully to prevent them from becoming licenses for freely polluting the air up to a stated limit. Especially for industrial air pollution, such a result could occur.

Under the new act such undesirable outcomes can be prevented in two ways. Firstly, industry can be compelled to use the best available technology, the best practical means to avoid air pollution. Secondly, a plant's emissions can be limited by taking account of other, nearby, emitters, which together are not allowed to surpass the established emission limit.

Such limits should not be looked upon only as values which should never be exceeded. The probability of transgression should also be considered. It will be clear too that the limits need not be applied everywhere, but that they may differ according to the region. In an industrialized region they need not be the same as in a recreational area.

Even when all its details of the new act have been worked out, it will not be possible to handle air pollution by simply applying the assessed rules. In contrast to the quarrels between the bleachers and brewers in former days in Haarlem, our recent experience with the establishment of new, big industries has taught us that consultation in an early stage of planning gives the best results. Above all an appreciation of the government's efforts for clean air for the sake of public health, and preparedness by industry to collaborate in these efforts is necessary. We in The Netherlands are fortunate that there is a growing awareness of the existing problem by Dutch industry, even when the measures to be taken will require considerable sacrifice.

New industries have to look at such sacrifices simply as a part of their condition for establishment. For existing, older factories which have to apply for a license on account of the new act, the situation may be more difficult. In some cases, depending on special conditions, such an undertaking may get financial support from a fund built up from contributions by all air polluters. The general rule that the polluter has to pay applies in The Netherlands to air pollution as well as to other froms of environmental contamination.

Beside all the implications of the air pollution act, it is necessary to point to the legislation for town and country planning which obliges municipalities to establish plans in which special areas can be indicated for industry, preferably outside residential areas. In general we must more and more strive in the future, as John Evelyn pointed out, for a situation with separated areas for industry, housing and recreation, not because we couldn't get the air pollution problem as such in hand, but rather because accidents and human faults will be unavoidable, whatever we do for the prevention of such events.

Although industry can be compelled to perform its own control measurements, the just-mentioned air pollution fund will also have to supply the resources for financing the general costs of the enforcement of the act. These costs may apply to man-power, not merely for the central government but also on regional levels where the amount of expertness is still rather scanty at this moment. Most importantly, the fund has to finance the measurements and measures for controlling air pollution. Those measurements are the responsibility of the licensing municipal and provincial authorities. The task of the central government is "to supervise the supervisor."

In order to get acquainted with the trend of the air pollution, a start has been made for establishing a national monitoring system. It will consist of 150 to 200 sampling stations, scattered over the country, for continuous automatic monitoring of sulphur dioxide with telemetering of data to one central point, the State Institute of Public Health (Rijks Instituut voor de Volksgezondheid) at Bilthoven. It is intended that the monitors will in the future also measure other components, such as nitrogen oxides and ozone. The complete system is supposed to be in operation within five years. It is being developed as an integrated system which does need to be serviced at only three month intervals. The results will be continuously available at the central institute.

It is intended that regional and local monitoring systems be connected with the national network. Some of these smaller systems, with a greater sampling density, are already in operation.

Of course the new act has its sanctions. Of the penalties, created by King Edward I, we don't think any longer about confiscation of goods, but the closing down of an undertaking is still possible. As to today's desire of some people to torture the managers of some polluting factories, we hope to sublimate these aggressive feelings into a better and more adequate understanding of the existing problems.

For that purpose, more research will certainly be necessary. The Organization for Applied Scientific Research (T.N.O.) has already made a significant start on such work and important investigations are well under way. Other institutes are doing the same and there is close cooperation with industry as well as with institutes abroad.

International cooperation is indispensable for a small country like The Netherlands. Our country takes part in many international commissions and a start has been made for close cooperation with the adjacent countries, West Germany and Belgium, first of all, for laboratory research.

Our Queen, when she opens the discussions in our Parliament on the third Tuesday in September, every year, always ends her speech with the prayer that God may give wisdom and power. We all are facing a heavy task and a great responsibility for which we too will need wisdom and power.

EVALUATION OF THE PRESENT SITUATION AND THE GENERAL TRENDS OF ACTIVITY IN THE PROTECTION OF THE AIR IN POLLAND

By Jacek Janczak
Director of Air Pollution Control Office
Central Water Resources Administration
Warsaw, Poland

The protection of atmospheric air against pollution occupies a key position in the complex of problems related to the protection of man's environment.

A skyrocketing growth of the negative effects can be seen when specified size of production is exceeded, and, along with it, the volume of substances issued into the atmosphere by the power, chemical and metallurgical industries concentrated in relatively small industrialized areas. Motor traffic makes things still worse. The adverse effects of the contamination of the air appear on a large scale in highly industrialized countries, particularly in the United States, but also in the Federal Republic of Germany, Britain, France, the German Democratic Republic and elsewhere. The disasterous smog that hit London in 1962, killing no fewer than 4,000 people is well known; similar cases were reported in Los Angeles, Donora, and other industrial centers. In highly industrialized countries the protection of the environment has become an economic and political issue. Statesmen and politicians pay particular attention to combating the contamination of the atmosphere and waters by industries. Equally well known is the report of the United Nations Secretary General U Thant of May 1969, some statements by President Nixon of the United States, Premier Chaban-Delmas of France, or by representatives of the governments of Holland, Sweden and other countries. In Poland, the Polish Committee for the Protection of Human Environment was set up at the Council of Ministers in 1970. Throughout the world intensive research is going on with a view to limiting the emission of dust and poisonous gases into the atmosphere, to finding new production technologies to eliminate the emission of pollutants, new methods of desulphurizing fuels and to developing highly efficient installations for reducing the pollution.

The Pollution of Atmospheric Air in Poland

The course of events in Poland corresponds to the mechanisms observed elsewhere in the world. It should be noted that weather conditions in Poland are generally less advantageous than in other countries. This is so because of the relatively high duration of meteorological calms (15 to 20 per cent in an average year) and the frequency of inversions (which occur every two to three days) that promote the growth of concentration of pollutants in the air.

The problem of air pollution is particularly acute in big industrial centers, chiefly in the Cracow-Silesia Industrial District and in the vicinity of huge industrial projects, such as the Lenin and the Bierut Iron and Steel Works, the Turoszow power plant, the Nitrogen Works at Pulawy, the

Plock refineries and petrochemical industries, the Aluminum Plant at Konin, the cement mills at Nowiny and Chelm, the sulphur basin in the region of Tarnobrzeg, and a score of other places.

The situation in the Upper-Silesian Industrial District and on the adjacent areas is becoming particularly serious in view of its rapid industrial development combined with the continued operation of many outdated industrial establishments, often built in the 19th century (some coke plants, zinc plants, iron and steel works, steam-engined hoisting machines in collieries, etc.), as well as with the fact that most houses in that region are heated by means of coal stoves. The chief fuel used in that region, both in industry and in homes, is coal with a high sulphur content. The degree of insolation in that region is smaller than elsewhere in the country. A rapid growth of damage can be seen in the area since 1962-1964.

Previously obtained knowledge of the degree of air pollution in Poland is unsatisfactory because of the small amount of reliable data, caused first of all by the lack of adequate measuring equipment. We do not yet have full economic and statistical data for determining the influence of air pollution on the environment. The observations that have been made and the measurements we do have at our disposal testify nevertheless to the increasing gravity of the problem of air pollution in this country.

A survey carried out in 1967 by the Ministry of Forestry and the Timber Industry indicates that 240,000 hectares of woodland, or three per cent of the total forest area in Poland, was damaged by air pollution.

No data have been obtained as yet regarding the degree and scope of the adverse effects of industrial pollution on agricultural production. In this domain it is particularly difficult to make an inventory of the losses because the life of agricultural plants is short when compared to forest flora.

Nevertheless, on the basis of observations made it can be assumed that the scope of adverse effects of industry on agriculture is also considerable. Pollution can directly cause a reduction of yields (the region of Olkusz), a decrease of the value of products from the point of view of consumption or processing (the region of Konin), or a destruction of crops (e.g., in the neighborhood of zinc plants, as in Miasteczko Slaskie). The concentration of some elements emitted by industry in the tissues or on the surface of plants can also lead to diseases and deaths of animals (fluorosis in the regions of Konin and Lubon) or even cause grave diseases in man (poisoning by food containing excessive quantities of nitrogen compounds).

The damage caused by industry is therefore serious, and will show an upward trend as industry continues to develop. The problem is becoming increasingly important from the point of view of the economy.

On the basis of a 1967 study embracing 14,000 industrial establishments it was possible to define the regions of the country in which there was a concentration of works which worst affect the environment. Over 300 factories were selected as the main sources of air pollution which should be the subject of anti-pollution moves prior to other establishments. These three hundred works are believed to be responsible for 50 to 60 per cent of the total emission into the atmosphere, which is estimated at 4 to 5 million tons of dust and 2 to 3 million tons of sulphur dioxide per annum. These selected establishments are being inventoried annually with respect to their emission of pollution. They emitted an estimated 2,339,000 tons of dust in 1967 as against 2,062,000 tons in 1970; whereas the amount of gaseous pollutants, chiefly sulphur dioxide, was defined as 1,159,000 tons in 1967 and

1,656,000 tons in 1970.

With the investment plans for the current five-year period it is estimated that the installed dedusting devices will be able to retain annually some 600-650 thousand tons of industrial dust. In other words, dust emission will be cut down by about five per cent every year despite a concurrent growth of industry. However, industrial growth will cause an increase in the emission of noxious gases, chiefly sulphur dioxide, of about 6 per cent annually. Throughout the world there are no know efficient and economical methods of curbing the emission of SO_2 produced during burning. The considerable growth of industrial production envisaged for the present five-year period will cause the appearance of this problem in more regions of the country. While it is estimated that the emission of dust by the examined works will be cut down by some 17 per cent (or 360,000 tons) as compared to 1970, despite significant growth of industry during that period, the emission of gaseous pollutants will rise by nearly 31 per cent over the 1970 figures.

In 1969 the Central Water Resources Administration outlined the general directions of activity in the field of air pollution control and for combating the effects of air pollution. This complex program of activity will be carried out as rapidly as resources allocated for the purpose will permit. The protection of the atmosphere is no simple matter and positive results can be obtained only by means of simultaneously solving of the problems discussed below.

Legislation

The first legal regulations concerning the protection of atmospheric air issued in 1954 authorized the setting up of appropriate bodies in the state sanitary inspectorate. The next step in this domain was the resolution of the Council of Ministers of 1961 concerning the lowering of air pollution in Poland, particularly in the Upper-Silesian Industrial District. Organized activity on a broad scale, however, began only when the Council of Ministers decreed in 1965 the setting up of the Bureau for the Protection of Atmospheric Air in the Central Board of Water Economy.

During the first period attention was focused chiefly on the preparation of a bill for the protection of atmospheric air against pollution, which was adopted by the Seym in 1966. Also a number of executive regulations were issued which established: permissible concentration of pollutants in the air; protection zones; the obligation to make measurements; permissible emissions; the principles of administering fines when the permissible level is exceeded, etc.

However not all parts of the bill have been fully implemented, because of limited means of action. No new legal acts are to be introduced in the immediate future, other than amendments to previous norms setting permissible levels of concentration of pollutants in the air, width of protective zones, etc.

Diagnosis

A knowledge of the concentration of pollutants in the air (immision), based on measurements, is the point of departure for the pursuit of a proper policy with regard to air pollution control.

Exception within the protective zones of individual works, measurements of pollution of atmospheric air are made by units subordinated to the Ministry of Health and Social Welfare. Factories are obliged to examine the concentration of pollutants in the air within their protective zones and measure the emission of pollutants. Units of the Central Water Resources Administration measure emissions for sake of control.

The Ministry of Health and Social Welfare has designed a nation-wide measuring network, which has so far embraced chiefly the areas of towns and settlements. At the moment this network, which is oriented mainly at measuring pollution from the point of view of the health of the population, is made up of some four thousand measuring posts scattered all over the country.

Measurements made so far consist in determining the amount of dust in the air at 2,500 places (using the sedimentation method) and the concentration of sulphur dioxide (using the contact method) in about 1,500 places. This has made it possible to obtain initial knowledge regarding the state of pollution of some regions of the country. However the methods employed, and the very diversified measuring equipment used, mostly home-made, do not allow the determination of short term concentration of pollutants nor of changes in concentration with time. The scope of measurement will be broadened as modern equipment is acquired.

The existing measuring network has so far not been adapted for signalling the occurence of pollution in excess of permissible concentration, such as may take place in highly industrialized areas during unfavorable weather. Neither is it able to supply information that will make it possible to lower the emission of pollutants in a critical situation. Therefore a special measuring network, a so-called alarm network, is to be set up and connected with the existing network. The new network is to be based on instruments which continuously determine the pollution of the atmosphere by dust and gases and which measure actual weather parameters. This will make it possible to forecast the level of air pollution.

The alarm network, which will be run by the State Institute of Hydrology and Meteorology, is planned to be set up in the worse polluted areas, such as the Silesia-Cracow Industrial District, and the regions of Plock or Konin. The system will signal the anticipated excessive concentration of pollutants, mainly of sulphur dioxide, which chiefly occur during still weater, inversions and fog. When these conditions appear it will, for example, be necessary to cut down the emission of sulphur dioxide from power stations by shifting temporarily to coal with a lower sulphur content or by lowering power generation while increasing it in plants situated outside the alarm area.

As for the measuring of the emission of pollutants in factories, the latter are obliged to measure the emission twice a year to provide a basis for checking the effectiveness of pollution control installations and for establishing the amount of pollution emitted. At the moment this obligation is not being met in full, if only for the lack of appropriate equipment; hence the amount of pollution is often determined on the basis of estimates.

Air protection units have been set up at fifteen voivodship laboratories for the examination of water and sewage, the aim of the units is first of all to take control measurements of the emission of pollutants from factories; further such units are being organized presently, but so far they are experiencing a scarcity of indispensable apparatus.

At present time, only two kinds of instruments for measurements of dust emission in stacks are manufactured in small quantities by the Automation and Mechanization Works at Kety. There is an urgent need to start in this country large-quantity production of fifteen more types of measuring instruments to meet the demand in this domain.

Investments Aimed at Curbing Pollution

Investment outlays in industry aimed at the protection of the atmosphere were first included in the National Economic Plan for the years 1966-1970 and amounted to 2,520 million zlotys. This included first of all the building of dedusting equipment and of installations for reducing some gaseous pollutants. This activity was concentrated in about two hundred works of five basic industries: mining and power, heavy industry, chemistry, engineering industry, and the building materials industry, which pose the worst threat to the environment, and which are situated in the five worst polluted voivodships: Katowice, Cracow, Opole, Wroclaw, and Lodz. Air protection in those regions accounted for nearly 62 per cent of the national total. The inventory of factories requiring special investment to prevent air pollution is updated every year by the Chairman of the Planning Commission at the Council of Ministers.

The proposed investment plan for the years 1971-1975 indicates the necessity of spending 4,000 million zlotys, or about 180 per cent of the sum actually spent in the period 1966-1970. Anti-pollution investment projects will be carried out in 216 factories. For the first time the plan also embraces light and food industries. The concentration of outlays in the worst affected voivodships listed above will continue and again about 62 per cent of the total outlay will be earmarked for these regions.

Other Means of Air Protection

During the last four years, i.e. since the law was enacted, a number of other undertakings aimed at limiting the amount of pollutants emitted into the atmosphere were started in addition to the installation of anti-pollution equipment. Worth mentioning here is the air-tightening of some production lines and plants; the shift from coal to gas or liquid fuel in some power generating installations; the replacement of steam engines by electric or diesel traction; and the introduction of central sources of heat. Besides this, high chimneys are being built to disperse pollutants, particularly sulphur dioxide, to a greater degree.

Although this activity has produced some effects, such as the decrease of emission and of the concentration of pollutants in the atmosphere, industry should nevertheless put greater emphasis on a broader introduction of changes to the techniques of production that cause high emission of pollutants. This trend can be observed throughout the world.

A considerable improvement of the quality of air in urban agglomerations is attributed to the development of central heating systems, development of gas supply and electrification of railways.

As was mentioned earlier, the development of motor traffic causes new problems connected with protecting the atmosphere. It seems absolutely necessary to solve the problem of desulphurization of oil and to improve the quality of petrol.

Siteing Policy

The conflict between technology and the natural environment, which grows in parallel with the progressing industrialization of the country, is caused among other things by errors in siteing industrial projects. The sharpness of the conflict may be reduced by a proper siteing policy, which requires proper knowledge of the existing background of air pollution (emission and imission), of geographical environment, the influence of physiographic conditions on the spread of pollutants, etc.

Until 1966 no consideration for problems of air protection against pollution was given while approving the siteing of new industrial projects. Consequently a number of big projects were improperly situated and the errors resulted in the devastation of the environment in their vicinity, for example the Nitrogen Works at Pulawy. But from 1966 on, the principle of studying the plans for construction of factories for potential pollution of the atmosphere has been the rule, although in some cases lack of necessary measurements has been an obstacle.

Such knowledge, backed by the results of study of the state of pollution, can serve as an argument for or against a proposed site for an industrial project. An improvement in this respect has been noted lately. It is intended that there be set up at the State Institute of Hydrology and Meteorology a special center for the elaboration of siteing expertise on air protection at new or developing industrial establishment sites.

Production and Use of Dedusting Equipment

Production of dedusting equipment is coordinated by the Ministry of Heavy Industry through "Klima-Went" Amalgamated Producers. The draft plan for the years 1971-1975 envisages a nearly twofold growth in the production of dedusting equipment as compared to the previous five years. This growth will result from the commissioning of new production centers and the development of an improved dedusting technology.

As a result, the home demand for dedusting installations should in principle be met around 1973. The program of development of this production can be viewed as adequate. On the other hand, the production of equipment designed to reduce the emission of gaseous pollutants is not sufficiently developed, particularly with regard to equipment for chemical industries.

In order to improve the efficiency of dedusting equipment, it is planned to intensify control activity. Fines are administered to factories that do not fulfil their duties. These fines contribute to the incentive for reduction of the emission of pollutants.

Research and Science Base

About forty research units, subordinated to individual ministries or to university schools, are presently engaged in research concerned with the protection of atmospheric air. Most of them, though, can hardly be classified as independent scientific units because of small staff (one to three specialists) and inadequate laboratory equipment.

In 1969 the coordination of research work was entrusted to the President of the Central Water Resources Administration, and this allowed an evaluation of research plans for the years 1971-1975 by the Council for the Protection of Atmospheric Air.

At present the main trends of research include problems of determining the conditions of dispersion of pollution in the atmosphere, of methods and installations for curbing the emission of dust and gases into the atmosphere, with particular emphasis on sulphur and nitrogen compounds, methods of measurements; and of designing measuring equipment. The necessities for the coming period include concentration on development of a scientific base, and improvement of the situation with regard to modern equipment and specialized instruments. Outlays for this research are to multiply ten times in the years 1971-1975 as compared to the previous five-year period.

Training

A proper staff of specialists is one of the basic needs for combating air pollution. The Central Water Resources Administration has worked out a program of postgraduate studies. Such training is already going on in the Silesian Polytechnic at Gliwice, at Warsaw Polytechnic and at Wroclaw Polytechnic. So far forty-eight persons have completed the course and ninety more still are undergoing training. The organizational and curriculum assumptions for a two-year school for graduates of secondary general education schools to be opened in 1971 has also been elaborated. A program of senior courses for those responsible for air protection in industry, and supervising this protection on behalf of people's councils, has also been worked out, and training begun in 1970 in the Central Water Resources Administration training center at Debe, with some seventy persons participating. Another program for the years 1971-1975 takes into account the needs of all branches of the economy and voivodship pollution-control bodies. All in all, the programs will provide additional training for 280 engineers in postgraduate studies and for 570 engineers and technicians in senior courses. A forecast of the demand for engineers and technicians skilled in pollution-control is being prepared for the period up to 1975 and up to 1985; it will serve as a basis for the organization of a network of schools.

Conclusion

In coming years, the protection of atmospheric air against pollution in Poland will concentrate on the following issues:

To acquire better knowledge of the pollution of atmospheric air, and

To reduce the emission of gaseous substances, particularly sulphur compounds.

Full knowledge of problems of dispersion of pollution will create a foundation for the pursuit of a proper industrial siteing policy and physical development of the country. Measurement of the degree of air pollution will provide the basis for the elaboration of a program of improving the situation in the worst affected areas, which will allow concentration of technical and financial resources. The creation of the alarm system will help to control the most polluting industries, among other things through burning fuels with low sulphur contents in unfavorable weather.

In view of the very limited possibilities of obtaining low-sulphur fuels it is demand necessary to undertake research into economical methods of desulphurizing exhaust fumes.

A replenishment of present equipment and the training of specialists will be indispensable in carrying on complex research into the aforementioned problems.

THE IMPACT OF ATMOSPHERIC CONDITIONS ON THE DISSEMINATION OF SULPHUR DIOXIDE

By Regina Hryniewicz
State Hydrological-Meteorological Institute
Warsaw, Poland

The state of pollution with sulphur dioxide of the atmosphere of an area under investigation depends, on the whole, on the amount of emissions of this gas in that area. However, the concentration of sulphur dioxide, measured in the near-soil layer, is determined by a number of other factors as well, such as meteorological and topographical conditions, and the occurence in the atmosphere of substances that may react with sulphur dioxide.

It is not always easy to define the impact of meteorological conditions on the concentration of sulphur dioxide, especially when the sources of emission are numerous and their characteristics are different, for example, short and tall chimneys, varying intensity of emissions and their location in the investigated area. As a rule, such a variety can be found in big urban agglomerations, where there are a lot of chimneys of home fireplaces, as well as industrial chimneys.

Since the measurements of sulphur dioxide carried out by the State Hydrological-Meteorological Institute are fragmentary, they do not permit full definition of the impact of atmospheric conditions on the state of pollution of a given area. At present, it is even difficult to know what methods should be applied in sampling air, in order to obtain a full account of the state of pollution of the atmosphere of a given area with minimum effort.

Sulphur Dioxide Concentrations Measured in the Near-Soil Layer

Measurements were carried out twice a day in one place in Warsaw over a period of 5 years. It has been found that sulphur dioxide concentrations changed in cycles within one year, from maximum values in the winter to minimum values in the summer. Similar changes in concentrations very often have been registered in other regions, for example, in Katowice, Cracow and Zakopane. A chronological course of average monthly concentrations in Warsaw-Bielany is presented in Table I, separately for 8 AM and for noon.

Such a course of monthly concentrations seems to be obvious because of the increased emissions of sulphur dioxide in the winter. However, the differences between summer and winter are greater than one might expect them to be, judging by the differences in emissions. The meteorological conditions in the winter are less conducive to the diffusion of pollution and to sulphur dioxide changing into other sulphur compounds, e.g. to serosols. As documented by measurements carried out in Warsaw in the winter, only abour 10 per cent of sulphur occurs in the form of sulphates. In the summer, however, this percentage increases to reach 30 per cent. In our climatic conditions, precipitation is higher in the summer. Therefore, sulphur dioxide is eluted by precipitation more effectively in the summer than in the winter, in spite of diminished emissions. On the basis of measurements of sulphate concentrations in precipitation, it has been found that the average amount of sulphur washed out of atmosphere by precipitation totals 5 kgs per hectare in the summer, and only 4 kgs per hectare in the winter. All these factors cause sulphur dioxide concentrations to be many times smaller in the summer. In Warsaw, summer sulphur dioxide concentrations are four times smaller in the morning, and five times smaller at noon, than those in the winter. It has been found in Katowice that a measurement station surrounded by a large number of sources of emissions registers greater differences between concentrations in both winter and summer, than a station located on the outskirts of the town. In the former this ratio is 3 to 4, and in the latter 2 to 3.

The data obtained in Katowice indicate indirectly that sulphur dioxide moves from the sources of emissions faster in the summer than in the winter. In the atmosphere, sulphur dioxide is not only dissipated mechanically, but also is absorbed intensively by basic dust particles, as well as oxidized, as a result of the influence of physico-chemical factors. Thus, when sulphur dioxide covers the distance from its sources of emission rapidly, more of it gets through than when it moves more slowly. Even if the phenomenon of mechanical elution of sulphur dioxide in the atmosphere did not exist, its concentration would gradually diminish, as a result of the influence of physico-chemical factors. Laboratory experiments and estimates show that in industrial regions the half-life of this gas varies by several hours.

The daily cycle of sulphur dioxide concentration depends, first of all, on the character of emissions in a given area. In Warsaw, concentrations are lower at noon than in the morning. In the winter, the noon concentration is about 78 per cent of that measured in the morning; in the summer, about 60 per cent. These figures for Cincinnati, U.S., are 80 per cent for the winter and 50 per cent for the summer. Thanks to favorable atmospheric conditions, the noon concentrations are lower than the morning ones. These differences are smaller in the winter than in the summer. In Katowice, however, a noon decrease in average monthly concentrations is observed only in the summer. In other seasons, the noon concentrations are the highest. This is due to a large increase of emissions from industrial plants and home fireplaces during the day. Measurements in Zakopane, where there are only chimneys of home fireplaces, indicate the existence of close interdependence between concentrations and the period of heating the ovens. Average hourly concentrations in two-week periods in Zakopane are presented in Table II.

The fluctuations of concentrations measured in Warsaw in the morning are illustrated by the distribution of concentrations presented in Table III. The distribution of concentrations is, more or less, logarithmic-normal. The differences of concentrations measured at short intervals of time in one place are very large from 0 to 700 micrograms per cubic meter. Such great differences occur during the whole measuring period, and not only in Warsaw. Even in Katowice, in a place surrounded by a large number of sources of emissions, measurements carried out at several-hour intervals revealed concentrations varying from zero to hundreds of micrograms per cubic meter. It can be said that change of sulphur dioxide concentration with time is a characteristic feature of these measurements. Similar fluctuations were observed in measurements carried out simultaneously in places situated several or ten-odd kilometers from one another. And again, it is a characteristic feature of the spatial distribution of sulphur dioxide concentrations. For example, the co-efficients of correlation of ranks for hourly concentrations were measured in three places in Katowice at the same time, on three different dates (Table IV). They vary from the value of +0.8 to -0.7 and are usually the highest at noon. This is probably due to more intensive air circulation, as a result of which sulphur dioxide mixes with the air better. In two places in Zakopane, situated 2 kilometers from each other, the co-efficient of average daily concentrations measured in February 1970 was 0.665, while the co-efficient of correlation for average fortnightly concentrations in terms of one hour increased to 0.91. Co-efficients of correlations of ranks between average daily concentrations in various places in Brussels varied from 0.4 to 0.8 and changed from month to month.

It follows from the above considerations that it is not easy to know which measuring stations in a given area are the most representative. Neither is it easy to define the indispensable minimum number of stations because of the extremely irregular distribution of sulphur dioxide concentrations in time and space.

The Interdependence of Average Monthly Concentrations of Sulphur Dioxide and Climatological Parameters

The average monthly concentrations in the morning in Warsaw have been analyzed based on measurements carried out over a period of 5 years. It can be assumed that between 1966 and 1970 no major changes took place in sulphur dioxide emissions in Warsaw. It should be stressed that the inflow of this gas from other regions is out of question because sulphur dioxide concentrations diminish very quickly as the gas moves away from the sources of emissions.

For each month, an average concentration over a period of 5 years has been calculated: $\overline{C}_{i5}$ and $\Delta C_i=\overline{C}_i-\overline{C}_{i5}$, where $\overline{C}_i$ is the average concentration for a given month in a given year. The results are presented in Table V. ΔC_i is the highest for winter months and the lowest for summer months. In Warsaw, because of the very low level of sulphur dioxide concentrations in the summer, as well as because of the small fluctuation in these concentrations, their analysis seems to be useless, taking into account meteorological conditions. It can be assumed that, with the existing level of emissions in Warsaw, meteorological conditions cause the gas to be spread well in the summer, and that fluctuations of meteorological parameters cause unimportant changes in concentrations, not very different from the generally low level. Only in December, January, February and March, are average concentrations higher, and fluctuations of these concentrations larger.

In the winter of 1966-1967, the lowest sulphur concentrations were recorded, and in the winter of 1968-1969, the highest. For these two periods, the results of analyses of certain climatological parameters will be presented. Deviations of average monthly values from the 5-year average have been calculated in similar manner to those for sulphur dioxide concentrations. The results of these calculations for temperature; monthly precipitation; number of days with precipitation; and average wind speed are presented in Table VI.

In the winter of 1966-1967, the deviations of temperature, monthly precipitation and the number of days with precipitation are positive, and in the winter of 1968-1969, negative. The deviations of the wind speed are small and no irregularities have been observed

The deviations of the directions of the wind from a 5-year average are presnted in Table VII.

In the winter of 1966-1967, there were more winds from the western quadrant and less from the eastern one; in the winter of 1968-1969, there were more winds from the eastern quadrant and less from the western one.

The data presented allow us to state that in certain periods climatological indices may indicate the influence of meteorological conditions on the state of atmospheric pollution even when they act in one direction only. For example, in the winter of 1968-1969, lower temperatures, lower precipitation, smaller number of days with precipitation and a high proportion of winds from the direction of the main sources of emissions resulted in an increase of sulphur dioxide concentrations. In the winter of 1966-1967, meteorological factors acted divergently: the temperatures were low, but the amount of precipitation and the number of days with precipitation were large.

The Influence of Meteorological Conditions on Average Hourly and Daily Concentrations of Sulphur Dioxide

The state of pollution of the atmosphere of a given region with a given emission is determined, first of all, by the dynamic state of atmosphere in the near-soil layer, characterized by the vertical temperature gradient and the vertical profile of wind speed.

However, not many of these data are available. For example, in the vicinity of Warsaw, the above-mentioned parameters are measured only twice a day.

In Zakopane, where measurements of sulphur concentrations are carried out, aerological measurements are not conducted. However, there are two synoptic stations, one located about 1,200 m. higher than the other, as well as two climatological stations located at intermediate altitudes.

Our fragmentary measurements of sulphur dioxide concentrations in Zakopane illustrate, to a certain extent, the influence of the vertical temperature gradient on the spread of pollution.

During one of the measurement periods, from December 22, 1969 to January 3, 1970, almost laboratory meteorological conditions occured. During that period, almost total calm prevailed, and there was no precipitation. The fluctuation of the vertical temperature gradient was the most important meteorological parameter that influenced the fluctuation of concentration. The gradient was established on the basis of observations at the above-mentioned synoptic and climatological stations rather than by the classic method. The dependence of sulphur dioxide concentration, in morning and evening hours, on the temperature in the place where air was sampled, as well as on the difference of temperatures measured at latitudes differing by 200, 700 and 1,200 m., were investigated. The method of selection of predicting variables worked out by Professor Z. Kaczmarek was applied. The highest co-efficient of correlation was obtained for the gradient of temperature occuring when the difference of altitudes was 200 meters. The co-efficient rose insignificantly when the vertical gradient of temperature at the altitude of 1,200 meters was included. Other parameters were of no meaningful importance. The joint co-efficient of correlations for two variables was 0.854.

In another measurement period, from January 18, 1971 to February 3, 1971, entirely different meteorological conditions existed. There was thaw, no inversion, nearly no precipitation, with several (ten-odd hour) periods of calm and or strong winds. In that period, winds had decisive influence on the state of pollution of the atmosphere. The dependence of the average daily concentration of sulphur dioxide on the number of hours of calm on that day was defined. A very close relationship was found, expressed by the rank correlation a co-efficient equal to 0.895.

Daily analyses of concentrations in Warsaw show that the negative gradient of temperature at altitudes not higher than 500 meters very often is accompanied by an increase in the sulphur dioxide concentration. This is confirmed by the fact that average concentrations in the period of inversion in a given month are always higher than average monthly concentrations at that time of the day. To illustrate this, concentrations during a period of inversion, measured in the morning, are compared with monthly averages in the winter of 1968-1969 as in Table VIII. As it results from the data presented, the differences are considerable.

However, temperature inversion is not always accompanied by an increase of sulphur dioxide concentration. For example, between October 13 and 17, 1969, inversions occured during the day (October 15 and 16) but no increases in sulphur dioxide concentrations were registered. At that time, there were clouds in the sub-inversion layer, it drizzled from time to time, and there were long periods of mist. There was a visible increase in dustiness, and an analysis of dust revealed a very high content of sulphates, reaching 25-30 micrograms per cubic meter, which was as much as the content of sulphur dioxide in air. An analysis of particles of mist and drizzle disclosed a concentration of sulphates reaching 150-400 milligrams per liter. Moreever, an increase of ammonium concentration in air was recorded. All this shows that in the period discussed mechanical elution was not effective, but there existed a number of conditions causing intensive transformation of sulphur dioxide into sulphates. This confirms observations made in the Soviet Union that in sub-inversion clouds the content of sulphates in urban areas is very high. It can be said that the clouds in a sub-inversion layer are a "broom" which sweeps sulphur dioxide out of the layer.

The pressure field exerts great influence on the state of pollution of the atmosphere. An introductory analysis of synoptic situations in a period of increased sulphur dioxide concentrations in Warsaw has shown that these are periods of barometric stagnation on the edges of cyclones, in cold fields, or in zones before approaching fronts after a period of stable barometric situations.

A study of the statistical relationship between hourly sulphur dioxide concentrations measured in Warsaw and certain meteorological parameters, calculated according to Professor Kaczmarek's method of selection of predicting variables, did not yield promising results. Joint co-efficients of correlations are not very high. In addition, different factors have decisive influence during different periods of measurement, and their number changes. For example, for a sample chosen at random from a three-year period, the joint co-efficient of correlation was 0.75 with 0.25 for 6 parameters. On the other hand, the joint co-efficient of correlation for the winter of 1967-1968 was 0.54, and only for three meteorological elements.

These results of statistical studies become understandable in the light of measurements in Zakopane, where, in the same year, fluctuations of sulphur dioxide concentrations were determined by inversions in one month, and by winds in another.

Of greatest importance for sulphur dioxide fluctuations in the period under investigation is the meteorological parameter which undergoes greatest fluctuation during that period. On the other hand, the level of concentrations at which fluctuations occur depends on the stable level of one or another meteorological paramenter that influences the spread of pollution. Again using the example of Zakopane, January 1970, when the temperatures were low and there was no precipitation or wind, the average sulphur dioxide concentration over a two-week period was 254 micrograms per cubic meter, while in the corresponding period of 1971, with no inversion or precipitation and with the temperatures above 0 degrees Centigrade, the average concentration over a two-week period was 64 micrograms per cubic meter.

During the first period, average hourly concentrations ranged from 50 to 1,500 micrograms per cubic meter, and during the second, from 0 to 500 micrograms per cubic meter.

Quantitative relationships between meteorological conditions and sulphur dioxide concentrations are not easy to define. In the years to come it will be necessary to carry on measurements of sulphur dioxide in order to define the state of pollution of the atmosphere. Meteorological forecast still does not allow quantitative determination of sulphur dioxide concentration in the atmosphere.

TABLE I

Average Monthly Sulphur Dioxide Concentrations in Micrograms per Cubic Meter in Warsaw-Bielany

		Month											
Year	Hour	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1966	8^{00}	57	57	30	32	17	7	14	13	27	34	31	36
	11^{30}	51	41	21	21	11	6	12	8	15	25	34	31
1967	8^{00}	54	41	55	56	37	22	17	31	35	38	66	81
	11^{30}	50	38	37	54	37	17	12	21	20	30	47	74
1968	8^{00}	108	68	52	38	24	9	16	44	23	66	43	119
	11^{30}	101	70	42	19	14	5	16	30	23	41	35	67
1969	8^{00}	152	138	114	40	32	25	20	23	23	21	41	63
	11^{30}	96	84	49	32	27	12	11	12	11	17	35	53
1970	8^{00}	88	108	63	36	15	22	20	12	17	13	20	29
	11^{30}	75	76	52	12	5	11	6	8	13	27	19	25

TABLE II

Average One and Two-Hour Sulphur Dioxide Concentrations in Micrograms per Cubic Meter in Zakopane in the Periods:
Dec. 22, 1969---Jan. 3, 1970
and
Feb. 7, 1970---Feb. 19, 1970

Hour	Average sulphur cioxide concentrations in the period		
	22.12-1969 3.1-1970	7.02-1970----19.02.1970	
	Rownia Krupowa	Rownia Krupowa	Sanatorium im.Chalubin
1	212	95	92
2	182		
3	111	99	70
4	140		
5	161	91	84
6	170		
7	259	174	91
8	283		
9	354	111	61
10	373		
11	321	70	52
12	248		
13	204	66	52
14	209		
15	223	91	51
16	263		
17	323	229	131
18	348		
19	346	241	155
20	299		
21	288	154	102
22	256		
23	228	115	92
0	226		

TABLE III

The Distribution of Sulphur Dioxide Concentrations from Hourly Measurements at 8 AM

The period investigated		Sulphur dioxide concentration in micrograms per cubic meter									
		Minimum	Distribution in per cent							Maximum	Arithmetic average
			10	30	50	70	90	95	98		
Autumn	1965	0	3	2	15	20	28	30	40	45	16
	1966	0	0	8	19	33	84	115	171	199	31
Winter	65/66	0	12	32	42	69	120	270	280	284	56
	66/67	0	0	7	19	61	130	154	176	193	44
Spring	66	0	2	9	15	30	60	95	110	118	27
	67	0	6	38	47	59	83	91	134	197	50
Summer	66	0	0	3	8	13	40	43	45	64	11
	67	0	2	10	16	31	38	56	118	120	24
Whole year 1.9-66 31.8-67		0	0	10	26	46	87	117	155	199	37

TABLE IV

The Co-Efficient of Correlations of Ranks for Sulphur Dioxide Concentrations Measured in Three Places in Three Hourly Periods in Katowice

1-Warszawska 2-Planetarium 3-Airport

Measurement Points	1---2		1---3		2---3		
The date of Month/measure	7^{00}	12^{00}	7^{00}	12^{00}	7^{00}	12^{00}	19^{00}
I 1969	0.585	0.774	0.512	0.501	0.601	0.356	
II 69	0.727	0.485	0.632	0.516	0.590	0.694	
III 69	0.454	0.496	0.216	0.708	0.450	0.535	0.383
IV 69	0.597	0.609	0.629	0.446	0.378	0.316	-0.171
V 69	0.632	0.646	0.433	0.807	0.470	0.880	0.091
VI 69	0.479	0.249	-0.048	0.343	0.514	0.325	0.335
VII 69	-0.092	0.173	0.478	0.597	0.152	0.059	0.077
VIII 69	0.442	0.502	0.183	0.277	0.234	0.259	0.089
IX 69	-0.103	0.127	-0.086	0.436	0.032	0.535	0.439
X 69	0.424	0.510	0.059	-0.082	0.434	-0.752	0.011
XI 69	-0.071	0.567	0.020	0.593	0.110	0.169	0.445
XII 68	0.290	0.512	0.248	0.461	0.248	0.385	

TABLE V

Deviations of Average Monthly Concentrations from Monthly Average in 5 Years

Month	$\bar{c}_{i5}$ Average sulphur dioxide concentration in 5 years in micrograms per cubic meter	$\Delta c_i = \bar{c}_i - \bar{c}_{i5}$ Difference between average monthly sulphur dioxide concentrations and and average concentrations in 5 years in micrograms per cubic meter				
		1966	1967	1968	1969	1970
I	91.5	-34.7	-38.0	+16.2	+60.0	-3.7
II	82.5	-25.1	-41.6	-14.5	+55.7	+25.4
III	62.7	-32.5	-7.6	-11.0	+51.0	+0.3
IV	40.2	-8.2	+16.1	-2.7	-0.4	-4.6
V	24.9	-8.4	+12.5	-1.0	+6.7	-9.6
VI	16.9	-9.6	+5.4	-8.1	+7.8	+4.6
VII	17.5	-3.7	-0.1	-1.2	+2.3	+2.8
VIII	24.6	-11.6	+6.6	+18.9	-1.2	-12.6
IX	25.1	-2.3	+9.9	-1.8	-1.9	-8.6
X	34.6	-0.8	+3.8	+31.8	-13.8	-22.2
XI	39.9	-8.5	+25.7	+3.0	+0.6	-20.4
XII	65.9	-29.4	+15.3	+53.6	-3.0	-36.2

TABLE VI

Monthly Averages in 5 Years and Deviations from These Averages for Winter Months: Temperature, Monthly Precipitation, the Number of Days with Precipitation, the Wind Speed

Month	$\bar{t}_{i5}$ Average monthly temperatures in 5 years in Centigrade °C	$\Delta t_i = \bar{t}_i - \bar{t}_{i5}$ Difference between the average temperature of a month and the 5 year average for this month in Centigrade		$\bar{h}_{i5}$ Average monthly precipitation in 5 years in millimeters mm	$\Delta h_i = h_i - \bar{h}_{i5}$ Difference between monthly precipitation and monthly averages in 5 years in millimeters		$\bar{n}_{i5}$ Average monthly number of days with precipitation in 5 years Number of days	$\Delta n_{i5} = n_i - \bar{n}_{i5}$ Difference between monthly number of days with precipitation 5 year average Number of days		$\bar{v}_{i5}$ Average monthly speed of wind in 5 years in meters per second	$\Delta v_i = \bar{v}_i - v_{i5}$ Difference between average monthly speed of wind and 5 year average in meters per second	
		1966/ 1967	1968/ 1969		1966/ 1967	1968/ 1969		1966/ 1967	1968/ 1969		1966/ 1967	1968/ 1969
XII	-2.9	+2.6	-1.4	43.1	+18.7	-39.5	18.4	+6.6	-14.4	2.6	+0.5	-0.9
I	-5.9	+0.7	-1.6	37.2	-0.7	-26.8	17.4	+0.6	-6.4	2.9	+0.2	+0.2
II	-3.4	+2.6	-2.2	30.9	+20.1	-13.9	14.8	+1.2	-5.8	3.1	-0.4	+0.7
III	+0.1	+3.2	-4.3	31.3	+20.2	-12.2	15.0	+8.0	-6.0	3.2	0.0	+0.1

Table VII

Deviations of monthly wind roses from 5-year monthly averages

Month	$\overline{N}_{i5}$	$\Delta N_i = N_i - \overline{N}_{i5}$		$\overline{NE}_{i5}$	$\Delta NE_i = NE_i - \overline{NE}_{i5}$		$\overline{E}_{i5}$	$\Delta E_i = E_i - \overline{NE}_{i5}$		$\overline{SE}_{i5}$	$\Delta SE_i = SE_i - \overline{SE}_{i5}$		$\overline{S}_{i5}$	$\Delta S_i = Si - \overline{S}_{i5}$		$\overline{SW}_{i5}$	$\Delta SW_i = SW_i - \overline{SW}_{i5}$		$\overline{W}_{i5}$	$\Delta W_i = W_i - \overline{W}_{i5}$		$\overline{NW}_{i5}$	$\Delta NW_i = NW_i - \overline{NW}_{i5}$		$\overline{C}_{i5}$	$\Delta C_i = C_i - \overline{C}_{i5}$	
		66/67	68/69		66/67	68/69		66/67	68/69		66/67	68/69		66/67	68/69		66/67	68/69		66/67	68/69		66/67	68/69		66/67	68/69
XII	1.5	-1.5	-1.5	2.1	-2.1	-1.1	1.7	+0.8	+1.8	2.4	+0.6	+3.1	4.0	+5.0	+1.0	5.3	-1.3	-4.3	5.4	-1.9	-0.9	3	0	-0.5	5.6	+0.4	+2.4
I	2.0	-1.0	-0.5	2.8	+0.2	-2.3	4.8	-3.3	+6.2	4.0	-1.0	+6.0	2.0	+0.5	+0.5	3.9	+3.1	-1.9	4.2	+1.3	-4.2	3.3	+1.2	-1.8	4.0	-1.0	-1.0
II	0.9	+0.1	+0.1	2.0	-2.0	-1.5	5.0	-2.5	+9.5	4.9	-0.4	+0.6	2.4	+2.1	-0.9	3.7	+0.8	-2.2	3.7	+2.3	-2.2	2.0	-1.0	-2.0	3.6	+0.4	-1.6
III	0.5	-0.5	0.0	3.6	-3.6	+10.9	2.9	-2.4	+2.6	2.1	+0.9	-1.6	2.7	+1.8	-0.7	7.0	-1.5	-4.0	6.6	+1.4	-4.1	2.8	+1.3	-1.3	2.8	+2.2	-1.8

TABLE VIII

Average Concentrations Within Month and During Periods of Inversion of Temperature at an Altitude Not Higher Than 500 Meters

Month and Year	XII.68	I.69	II.69	III.69
Number of days with inversion at altitude not higher than 500 meters	10	16	8	6
Average sulphur dioxide concentrations in periods of inversion of temperature	174	201	258	278
Average monthly concentrations mg SO_2/m^3	108	152	138	114

PERIODICAL MEASUREMENTS OF ATMOSPHERIC POLLUTION AND THEIR INTERPRETATION

By Andrzej Kasprzycki
State Hydro-Meteorological Institute
Warsaw, Poland

Introduction

In meteorological conditions causing the highest increase of the concentration of pollution in a given area, there arises the need to conduct periodical measurements of pollution immissions in the lower layer of the atmosphere. The aim of these measurements should be to gather the greatest possible amount of information on pollution at the lowest possible cost.

Let us assume that we are given a set of measurements of atmospheric pollution $X_1, X_2, \text{-----} X_n$, obtained in a certain area at a definite date, forming an n-element random sample. The question is what the scatter diagram of such a set should be like, in order to obtain maximum information about the investigated phenomenon, with fixed index n (the number of measurements). Introducing in the analyzed diagram statistical measure of information I (Z) equal to (3):

$$I(X_1, X_2, \ldots X_n) = H(X_1) + H(X_2) + \ldots + H(X_n) - I(X_2 \mid X_1) - \ldots - I(X_n \mid X_1, X_2, \ldots X_{n-1}) \qquad \text{(Eq. 1)}$$

where: $H(X_i)$= entropy of the set, from which the element X_1 has been selected

$I(X_i \mid X_1, X_2, \ldots X_{n-1})$= statistical measure of information about the set from which the element X_i comes. The information has been obtained as a result of observations of the $X_1, X_2, \ldots X_{n-1}$ sequence of elements. It is evident that the $X_1, X_2, \ldots X_n$ obtained from the random sample will be maximal, when all conditional measures of information $I(X_i\ X_1, \ldots X_{i-1})$ will equal zero, or when the random sample will be independent in space and time. On the basis of the results of numerous experiments made so far, it can be said that meteorological conditions, as well as concentrations of atmospheric contaminants constitute a random field in space, and a stochastic process with continuous parameters in time. Thus the temporal-spatial field of atmospheric pollution at each point has a definite, normalized correlation function $r(t-t_0; \vec{\rho})$, one that: $r(0; \bar{0}) = 1 \quad r(\infty; \vec{\rho}) = r(t-t_0; \infty) = 0$

We arrive at the conclusion that both in space and time, there exists a radius of correlation of the considered measuring sequence, which may be defined by the following relationships, sufficient for the task set:

The radius of correlation of stochastic process T -

$$\lim_{t-t_0 \to T^-} r(t-t_0; \vec{0}) \leq 0.2 \qquad \text{(Eq. 2)}$$

The radius of correlation of random field R -

$$\lim_{|\rho| \to R^-} r(0;\vec{\rho}) \leq 0{,}2 \qquad |\vec{\rho}| = \sqrt{(x-x_0)^2+(y-y_0)^2+(z-z_0)^2} \qquad \text{(Eq. 3)}$$

Drawing practical conclusions from the above considerations, it can be stated that:

Measurements of instantaneous values of the concentration of atmospheric pollution at a fixed measuring point should be carried out at time intervals t, bigger than the radius of correlation T of the stochastic process formed by this measuring sequence.

Measurements in a selected threatened area should be carried out at distances exceeding the radius of correlation of the random field R.

Summing up, it can be said that for control of the air quality of a region, when an instrument for continuous measurement of the concentration of atmospheric pollution is available, it is useful to carry this instrument from one place to another during the period of periodical measurements.

The Interpretation of Permissible Norms of Pollution of the Atmosphere

Adherence to the permissible norm of concentration of atmospheric contaminants in a region can be ensured only by never exceeding both normalized average daily concentrations and average 20 minute concentrations. Control measurements should seek to find out whether these concentrations have been exceeded and if they have, in how many cases. The confidence interval of the results obtained is dependent on the weight of the problem considered. For example, in the case of emissions of highly dangerous substances to the atmosphere, the measurements of immissions in the protected area should be conducted continuously, in order to ensure an almost 100 per cent confidence interval. The establishment of a permissible annual distribution function and estimation of the percentage range of the normalized quantile do not ensure a high enough degree of atmospheric protection for the following reasons:

The concentrations of contaminants in the atmosphere constitute temporal sequences with a high degree of auto-correlation ($r > 0.5$). Thus, when the permissible norms are exceeded, the phenomenon is not sporadic, but of long-lasting character.

Yearly distribution functions do not fulfill the requirements of the ergodic process, that is, their expected value in time is not equal to the expected value in the space of variability of pollution concentrations in terms of probability calculus.

Yearly statistical time series are not statistically homogenous, that is, they are determined by the random variability of the investigated phenomenon only.

The Statistical Distribution of Pollution Concentrations in the Near-soil Layer of the Atmosphere

Let us support that $\rho(X_0, Y_0, Z_0)$ denotes the concentration of any passive atmospheric pollutant in the point of the spatial field X_0, Y_0, Z_0, and that

ξ means any random fluctuation that causes a change in concentration of a given pollutant in the discussed point in space. In the case of the field of atmospheric pollution in an area without sources, the following relationship, limited to the terms of the first order, is evident:

$$\frac{\partial\rho(x_0, y_0, z_0, t)}{\partial t} \sim \xi\nu\rho(x,y,z,t) \qquad \text{(Eq.4)}$$

Thus, the change of the concentration of the pollutant can be considered as proportional to the random value ξ and the concentration of the substance in the atmosphere $\rho(x,y,z,t)$ in this point of the field, in which, as a result of random fluctuations, there occurs the transformation of the substance $d\tau$ to the point of the field with the coordinates X_0, Y_0, Z_0 in the time dt.

Taking account of the fact that the local time derivative $\frac{\partial\rho(x_0, y_0, z_0, t)}{\partial t}$ in the field of the meteorological element is connected with the time derivative of the particle $\frac{\partial\rho(x,y,z,t)}{\partial t}$ by the relationship(1)

$$\frac{\partial\rho(x_0, y_0, z_0, t)}{\partial t} = \frac{d\rho(x,y,z,t)}{dt} - \vec{\nu}\cdot\text{grad}\ \rho(x,y,z,t) \qquad \text{(Eq. 5)}$$

where $\vec{v}$ - wind spead,

$\vec{\nu}\ \text{grad}\ \rho\ (x,y,z,t)$ convective derivative,

we obtain:

$$\xi\nu\, dt \sim \frac{d\rho(x,y,z,t)}{\rho(x,y,z,t) + \vec{\nu}\,\text{grad}\ \rho(x,y,z,t)} \qquad \text{(Eq. 6)}$$

We will notice that in the case of the field of atmospheric pollution generated by point sources, increase of wind speed causes a diminution of pollution concentration and of the gradient of this concentration in a given point of the field, which is evident intuitively. Taking further into account that $\vec{\nu}$ and $\text{grad}\ \rho\ (x,y,z,t)$ are always collinear, we arrive at the conclusion that in a fixed point of the stationary field of pollution, the convective derivative, exact to terms of the second order, can be considered as a constant quantity, characteristic for this point of the field.

On the strength of the central limit theorem, proved in elementary statistics, the sum of the sufficient quantity of random variables influencing the investigated phenomenon has a normal distribution. Thus, in the case considered, it will be the function $\sum_{\nu}\xi$ that will have a normal distribution in a given point of the field, which results directly from the limiting qualities of the expression:

$$\lim_{n=\infty}\sum_{y=1}^{n}\xi\nu = \int\frac{d\rho}{\rho+c} = \log(\rho+c) \qquad \text{(Eq. 7)}$$

$$\text{where}\quad c = \vec{\nu}\cdot\text{grad}\ \rho(x,y,z,t) = \text{const.}$$

It follows from the above considerations that passive pollution of the atmosphere has a logarithmic-normal distribution. This has also been confirmed by experiments of numerous authors, for example(2,4). Such a distribution can be sufficiently defined by three parameters: m - mathematical expectation, or the expected value of the logarithms of concentrations, σ_i^2 the variance of the logarithms of concentration, C constant.

Estimation of the Parameters of the Distribution Function of Atmospheric Pollution on the Basis of Measurements

Having at our disposal the results of measurements of immissions of atmospheric pollution in a given area, it is possible to estimate the distribution function of pollution concentration if the following requirements, resulting directly from the above considerations, are fulfilled:

1. All measures have the same averaging time, that is, are 20-minute measurements, one-hour measurements, etc.
2. They come from a period meteorologically homogenous, that is, do not exceed a monthly time interval and are obtained under, more or less, the same meteorological conditions, for example, in a period of drought, with winds prevailing from one direction during a period of stagnation, etc.
3. They come from the same time of day, or if from individual times of day, their number is the same (e.g. in the case of the 24-hour average concentration of pollution, on the basis of 20-minute measurements).
4. They cover an area which can be regarded as homogenous from the point of view of the statistical distribution of pollution, that is, having similar vegetation and relief, and spatial dimensions much smaller than the distances from the basic sources decisive in a given meteorological situation (for example, a fixed wind direction) on immissions in a given area.

In the remainder of this paper, I will confine myself to a presentation of a method for estimating the parameters of the log-normal distribution function of atmospheric pollution with the application of electronic computing techniques. A detailed analysis of the method of estimation of the parameter m_i σ_i^2 C is presented in reference 5.

We introduce a new variable, determined by Equation 7, that means $Z=\log(\rho + C)$. Later we postulate that variable to possess a normal distribution, determined by the density function:

$$f(z)=\frac{1}{\hat{\sigma}\sqrt{2\pi}}\exp\left(-\frac{(z-\hat{m})^2}{2\sigma^2}\right)=N(z;\hat{m};\hat{\sigma}) \qquad \text{(Eq. 8)}$$

From 7 and 8 it follows, that the three parameters $\hat{m}$, $\hat{\sigma}$, $\hat{C}$ completely determine the statistical distribution of the random variable ρ. Now we estimate these parameters by the method of moments. By the definition of population moments we have:

$$E(\rho)=\int_{-\infty}^{\infty}\rho\, g(\rho)\,d\rho$$

$$E(\rho-m)^k=\int_{-\infty}^{\infty}(\rho-m)^k\, g(\rho)\,d\rho \qquad \text{(Eq. 8.1)}$$

where $g(\rho)$ is the density function of the random variable.

We now make a simplifying assumption;

$$g(\rho)=0 \quad \text{for} \quad \rho\leq -C \qquad \text{(Eq. 8.2)}$$

where C any positive number.

That means we assume the random variable ρ + C to be positive at all times. According to the postulate of the method of moments, we accept as the estimation of proper moments of a general population, the moments computed by random sampling. Taking into account assumption 8.2, we can write:

$$\bar{\rho} = \frac{1}{N}\sum_{i=7}^{N}\rho_i \approx \int_{-C}^{\infty}\rho g(\rho)\,d\rho \qquad \text{(Eq. 8.3)}$$

$$m_k = \frac{1}{N-1}\sum_{i=1}^{N}(\rho_i - \bar{\rho})^k \approx \int_{-C}^{\infty}\rho g(\rho)\,d\rho$$

where $m_2 \equiv s^2$

According to the postulated thesis the following equation is valid:

$$g\left[\rho(z)\right]\rho'(z) = N(z;\hat{m};\hat{\sigma}) = f(z) \qquad \text{(Eq. 8.4)}$$

which immediately results from the general rules of the formation of the density function of transformed random variables (KACZMAREK 1970). The change of variables in Equations 8.3 corresponding to the inverse relation to Equation 7, implies $X=e^{Z} - C$, using Equation 8.4 after integration for the first order moment, and for the central moments of second and third order, yields following relations:

$$\bar{\rho} = \exp\left(m + \frac{1}{2}\hat{\sigma}^2\right) - \hat{C} \qquad \text{(Eq. 8.5)}$$

$$S^2 = \exp(2\hat{m} + 2\hat{\sigma}^2) - 2(\bar{\rho}+\hat{C})\exp\left(\hat{m} + \frac{1}{2}\sigma^2\right) + (\bar{\rho}+\hat{C})^2$$

$$m_3 = \exp\left(3\hat{m} + \frac{9}{2}\hat{\sigma}2\right) - 3(\bar{\rho}+\hat{C})\exp(2\hat{m}+2\hat{\sigma}^2) +$$
$$+3(\bar{\rho}+\hat{C})^2\exp\left(\hat{m}+\frac{1}{2}\hat{\sigma}2\right) - (\bar{\rho}+\hat{C})^3$$

The solution of this set of equations with respect to $\hat{m}$, $\hat{\sigma}$, $\hat{C}$ leads to following results:

$$m_3(\bar{\rho}+\hat{C})^3 - 3S^3(\bar{\rho}+\hat{C})^2 - S^6 = 0 \qquad \text{(Eq. 9)}$$

$$\hat{\sigma}^2 = \log\left[\frac{S^2}{(\bar{\rho}+\hat{C})}2 + 1\right]$$

$$\hat{m} = -\frac{\sigma^2}{2} + \log(\bar{\rho}+\hat{C})^2$$

The first of these equations has only one real root, which uniquely defines parameter C. It can be calculated by one of the numerical methods, or from the formula for the root of a 3rd degree equation. The empirical distribution function of the random sample of the investigated phenomenon in a given case of pollution of the atmosphere is described by the equation:

$$p(\bar{\rho} \leq \rho o) = \frac{1}{\hat{\sigma}\sqrt{2\pi}} \int_{-\infty}^{\rho o} \frac{1}{\sigma + \hat{C}} \exp\left\{-\frac{\mu g(\rho + \hat{C}) - \hat{m})^2}{2\hat{\sigma}^2}\right\} d\rho \qquad \text{(Eq. 10)}$$

As previous experience shows$^{(5)}$, in an overwhelming majority of cases, Equations 9 proves to be sufficient for measuring atmospheric pollution. However, it sometimes happens that a negative value of parameter $\bar{C}$ results from calculations, with a modulus exceeding the smallest element of the random test. In this case, it is necessary to assume that $\bar{C}=0$ and use in further calculations the following estimators:

$$m = \frac{1}{N}\sum_{i=1}^{N} \log \rho_i \qquad \hat{\sigma}^2 = \frac{1}{N-1}\sum_{i=1}^{N} (\log \rho_i - \hat{m})^2 \qquad \text{(Eq. 11)}$$

The Estimation of the Rank of the Normalized Quantile on the Basis of the Distribution Function

As was said at the beginning, the confidence level of conclusions to be drawn from measurements should be assumed initially, in accordance with the aim they are to serve. Passing to the confidence intervals of the parameters of the logarithmic-normal distribution function, we shall notice that, as it was proved in Reference 5, the exact Equations are practically useless. For large random samples the two first parameters can be estimated with the help of the normal confidence interval:

$$\hat{m} - \frac{t\alpha\hat{\sigma}}{\sqrt{N}} < m < \hat{m} + \frac{t\alpha\hat{\sigma}}{\sqrt{N}} \; ; \; \hat{\sigma} - \frac{t_\alpha\hat{\sigma}}{\sqrt{2N}} < \sigma < \hat{\sigma} + \frac{t_\alpha\hat{\sigma}}{\sqrt{2N}} \qquad \text{(Eq. 12)}$$

where: t_α = the number from the tables of the density of the normal distribution $N(0;1)$, which corresponds to the confidence level $1-\alpha$;
$\hat{m}\,\hat{\sigma}$ = point estimations of the parameters from Equations 9 or 11.
N = the size of the sample.

Next, confining the discussion to norms for 24-hours and 20-minute sampling times, there are three basic cases, namely:

The data allow us to state that the permissible norms of pollution of the atmosphere have not been exceeded at the assumed confidence level.

The data allow us to state that the permissible norms of pollution of the atmosphere have been exceeded at the assumed confidence level.

The data do not allow us to decide whether the permissible norms of pollution concentration in the atmosphere have been exceeded, or not at the assumed confidence level.

Let us assume that the measurements were conducted during k meteorologically homogenous days. In this case, as it was explained in Reference 2, the rank of the percentage of the normalized 20-minute quantile, estimated on the basis of the empirical distribution function, should not be higher than:

$$P_{20^m} = \left(1-\frac{20^m}{24\,60^m}\right)100\,\% = 98.61\,\% \qquad \text{(Eq. 13)}$$

which ensures protection against exceeding the normalized 20-minute concentration at a confidence level assumed in advance during a period of one day.

In the case of continuous measurements(1) with an averaging time not longer than 20 minutes in the analyzed k-day time interval, the parameters of the distribution of 20-minute concentrations $\hat{m}$ $\hat{\sigma}$ $\hat{C}$ will be true values of these parameters in this interval, but, at the same time, will remain estimators of unknown parameters in relation to the defined meteorological situation (in k-day interval). In accordance with the hypothesis previously presented, the distribution function of the logarithms of concentrations $Z_{ij} = \log(\rho_{ij}+\hat{C})$ is defined by the normal frequency function $N(z;\hat{m};\hat{\sigma})$, while the distribution function of average daily logarithms of concentrations

$$\bar{z}_j = \frac{1}{72}\sum_{i=1}^{n}\log(\rho_{ij}+\hat{C}) \qquad j=1,2,---k$$

is determined by the frequency function $N(\bar{z};\hat{m};\frac{\sigma'}{\sqrt{72}})$, which is a direct result of statistical properties of the distribution function of a mean of random variables, with the assumption that the size of the sample is

$$n = \frac{24\cdot 60^m}{20^m} = 72$$

Of course, $\bar{\bar{z}} = \frac{1}{k}\sum_{j=1}^{k}\bar{z}_j = \frac{1}{N}\sum_{ij}^{N} z_{ij}$, where, in the case of continouus measurements N=72k.

The percentage rank of the average daily normalized quantile, estimated on the basis of a distribution function defined as above, should not be greater than:

$$P_{24^n} = \left(1-\frac{1}{k}\right)100\,\% \qquad \text{(Eq. 14)}$$

where k is the number of days in a meteorologically homogenous time interval. This condition constitutes sufficient protection against exceeding the average daily normalized concentration if the series of measurements is really statistically homogenous.

In the logarithmic-normal distribution, the rank of every quantile is expressed(5) by the formula:

$$P_x(\rho<\rho_x) = \phi(t_x;0;1) \qquad \text{(Eq. 15)}$$

where $t_x = \frac{1}{\sigma}\{\log(\rho_x + C) - m\}$ and $\phi(t;0;1)$ is the function of the normalized normal distribution, (with the expected value 0 and the variance 1). When the results obtained allow us to state that the normalized concentration of pollution has not been exceeded, the following equations must be satisfied:

For the 20-minute norm: $P(\rho<\rho_{20^m}) = \phi(t'_{20^m};0;1) < 0.9861$ (Eq. 16) where $\rho_{20}m$= the normalized 20-minute concentration of the pollutant,

$$t^{I}_{20}m = \frac{\log(\rho_{20}m+\hat{C}) - \left(\hat{m} - \frac{t\alpha\hat{\sigma}}{\sqrt{N}}\right)}{\hat{\sigma} - \frac{t\alpha\hat{\sigma}}{\sqrt{2N}}}$$

For the 24-hour norm of the pollutant:

$$P(\rho<\rho_{24}n) = \phi(t^{I}_{24}n;0;1) < 1 - \frac{1}{k} \qquad \text{(Eq. 17)}$$

where $\rho_{24}n$ the normalized 24-hour concentration of the pollutant

$$t^{I}_{24}n = \frac{\log(\rho_{24}n+\hat{C}) - \left(\hat{m} - \frac{t\alpha\hat{\sigma}}{\sqrt{N}}\right)}{\frac{\hat{\sigma}}{\sqrt{72}} - \frac{t\alpha}{\sqrt{72}}\,\frac{\hat{\sigma}}{\sqrt{2N}}}$$

To allow us to state that the permissible norms of atmospheric pollution are exceeded at the assumed confidence level, the following inequalities must be fulfilled:

$$P(\rho<\rho_{20}m) = \phi(t^{II}_{20}m;0;1) > 0.9861 \qquad \text{(Eq. 18)}$$

where $$t^{II}_{20}m = \frac{\log(\rho_{20}m+\hat{C}) - \left(m + \frac{t\alpha\sigma^{I}}{\sqrt{N}}\right)}{\hat{\sigma} + \frac{t\alpha\sigma^{I}}{\sqrt{2N}}}$$

For the 24-hour norm

$$P(\rho<\rho_{24}n) = \phi(t^{II}_{24}n;0;1) > 1 - \frac{1}{k} \qquad \text{(Eq. 19)}$$

where $$t^{II}_{24}n = \frac{\log(\rho_{24}n+\hat{C}) - \left(\hat{m} + \frac{t\alpha\sigma^{I}}{\sqrt{N}}\right)}{\frac{\hat{\sigma}}{\sqrt{72}} - \frac{t\alpha}{\sqrt{72}}\,\frac{\hat{\sigma}}{\sqrt{2N}}}$$

In Equations 16 through 19, t_α mean absissas of the normal standardized distribution in the case of sample size N bigger than 100, or the absissas of the students "t" distribution for N-2 degrees of freedom in the case of a sample size smaller than 100, for the confidence level $1-\alpha$.

If, on the basis of the parameters estimated through m, o, C measurements, it is not possible to determine that the inequalities 16 and

17, as well as 18 and 19 are fulfilled, then, at the assumed confidence level, the data do not permit us to decide whether or not the permissible norms of the concentration the pollutant in the atmosphere have been exceeded.

It should be also stressed that, in the case of exceeding the normalized concentration of atmospheric pollution, the left side of the inequality 18 or 19 also defines the level of danger to the atmosphere, which can be interpreted as certain at the assumed confidence level.

Conclusion

The above considerations lead to the following important conclusions:

1. Control measurements of immissions of pollution in protected areas should be conducted only when meteorological conditions are unfavorable in the investigated region.
2. Areas in which measurements are to be conducted should be selected on the basis of a cartographic-mathematical analysis(2), when meteorological conditions are definitely considered to be dangerous.
3. It is advisable to carry out mobile measurements in selected areas in order to minimize the time series correlation and to maximize the representativeness of measurement series for a given area.
4. The confidence level of the results obtained should be determined only by the degree of harmfulness of the investigated pollutant and by economic effects connected with exceeding the normalized quantities of atmospheric pollution.
5. A comparison of the results of measurements of immissions of atmospheric pollution in the form of distribution functions, as well as the hypothesis about the statistical logarithmic-normal distribution should be limited to periods of time in which the meteorological conditions can be regarded as qualitatively the same, (in a given region), and to areas homogenous with respect to the expected average immission of a given pollutant. A comparison of results in the form of a yearly distribution function of atmospheric pollution distorts the true picture of emissions in a given area and has no justification from the point of view of statistics.
6. In case the conditions defined in conclusion 5 are met, the use of the 2-parameter logarithmic-normal distribution is permissible only in the first approximation. When applying electronic computing techniques, it is necessary to introduce the 3-parameter logarithmic-normal distribution, as described earlier in this paper.
7. Permissible norms of atmospheric pollution should not be allowed to be exceeded a certain percentage of time in a 1-year period. In principle, the normalized concentrations of immissions should never be exceeded. Percentage ranks of normalized concentrations of atmospheric pollution, estimated in control measurements, define the degree of danger to the atmosphere in a given region in definite meteorological conditions when these values are exceeded.

Annotations

1. We have in mind continuous measurements, not correlated, which hypothetically can be carried out by moving the measuring instrument to the

next point of the polluted area and then returning to the initial point after a period of time equal to the radius of correlation of the time series considered.

2. We have in mind the definition of regions of maximal concentration of pollution, on the basis of the solution of the diffusion equation for given meteorological conditions and the main local emitters.

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DRY AMMONIA PROCESS FOR SULPHUR OXIDE NEUTRALIZATION

By Romuald T. Chrusciel
Vice-Chief Coordinator
for Abatement of Sulfur Oxides Emissions
Power Research and Testing Organization
"Energopomiar"
Gliwice, Poland

Contrary to the information spread by different firms and organizations, a technological process permitting sulphur oxides emission from large boilers to be effectively reduced has not been elaborated so far[1].

All the industrialized countries are carrying out studies aimed at the solution of this pertinent problem.

A necessity of independent research being carried out even by the countries of lower economic potential arises from the fact that the economics of the process will depend on the whole complex of conditions such as the site selection and weather conditions, raw materials and costs applicable individually to each power plant.

The experience gathered so far shows that the increase of nuclear power plant contributions to the total world balance of electrical energy production will not reach anticipated values within the nearest decades[2].

A lot of attention has been paid to the problem of SO_2 emission in Poland, where bituminous coal is the basic fuel used in power generation. Since our own research program was initiated four years ago we have been devoting considerable means for this purpose.

All of the research and experiments conducted in this field in Poland are coordinated by the Power Research and Testing Organization "Energopomiar" in Gliwice.

Among the technologies recognized throughout the world as most suitable for full scale application, the so-called "throw away" processes will be considered first (i.e. the method used by Combustion Ltd., dry additive method etc.[3]). This approach results from detailed cost analyses carried out for the processes designed as cost-returning as the size of the pilot plant increases.

New conceptions of the basic combustion process are considered next. In these the flue gas is obtained without toxic sulphur compounds (advanced gas--turbine steam--power cycles; combustion in fluidized bed[4]).

In the third instance processes of flue gas desulphurization with the recovery of commercially valuable sulphur are considered.

Final concern is for various processes for coal desulphurization.

The purpose of this paper is to present the principal results of studies on the original Polish technology for the "throw away" category.

This technology can be used intermittently as a means of intervention in case of particularly unfavorable weather conditions.

Polish air quality standards specify that the maximum average daily concentration of SO_2 in the atmospheric air should not exceed 0.35 mg/m^3, and the maximum average concentration over a period of 20 minutes 0.90 mg/m^3. The meteorological conditions leading to such concentrations occur in the climatic conditions of this country rather seldom and never over a period longer than 10% of the power plant annual operation time. The necessity to decrease the SO_2 emission, in the periods of excessive emission rate, arises first of all from the toxic influence of this pollutant on vegetation[5].

On the basis of the conclusions drawn from the references it may be expected that vegetation will be sufficiently protected if the occurence of concentrations, greater than the values specified by the standards can be prevented.

From the economic point of view it is apparent that the process of intermittent SO_2 limitation in the power plant must have low investment costs, as the installation is not operated on a continuous basis and the capital return period is consequently short.

The operating costs of such an installation can be relatively high as they will not greatly affect the overall cost of electrical energy production, due to the short operating periods.

To render its application technologically feasible the intermittent process must be as follows:

1. Flexible--short and easy start up and stopping

2. Reliable--little risk of maloperation

3. Should not result in major technological difficulties such as: circulating a large volume of solution or gas in the system; production of waste products--difficult to store; engaging additional staff, etc.

Our intervention method meets all the requirements stated above. It is based on an introduction of ammonia into the flue gas and the emission of the reaction products together with the remaining components of the flue gas into the atmosphere.

At the temperature and water vapor concentration conditions as well as acid anhydride concentrations occuring in power boiler flue gas, the formation of the reaction products in the form of crystals is not possible. The phenomenon of ammonium salt aerosol formation takes place at a certain distance from the stack outlet after the plume has been diluted with an appropriate amount of cold air. After lowering the temperature below the cyrstallization point a process of ammonium sulfite particle formation begins in the diluted plume. Particles of the order of 1 μ size are formed. The water vapor present in the plume facilitates the oxidation of sulfite to sulfate which takes place particularly fast in a solution.

Investigations carried out in many fields included:

1. The influence of ammonia flue gas neutralization products on animals. These experiments, conducted by a team of specialists from the Silesian Medical Academy, consisted of:
   a. introduction of the reaction products through the respiratory system of test animals (exposure to an atmosphere containing neutralization product aerosol)
   b. introduction with food

c. introduction by means of injections directly into viscera with a physiological salt solution.

The results obtained so far indicate that a marked protective action of flue gas neutralization by ammonia has been observed in the animals subjected to tests.

Table I presents the results of specialized experiments carried out on animals tested by inhalation (introduction of the agent to the body through the respiratory system).

Attempts to determine the mechanism of protective action have led to discovery of another advantageous effect i.e. the neutralization of nitrogen oxides present in flue gas. Some of the studies conducted so far have been published--references [6,7,8].

This year further tests are being carried out using real flue gas in one of the Polish power plants.

2. The influence of ammonia flue gas neutralization products on vegetation.

The experiments on the influence of ammonia flue gas neutralization products on selected kinds of vegetation were conducted by the Institute of Agriculture in Lublin and have included garden plot and test pot experiments.

Table II illustrates the protective effect of SO_2 ammonia neutralization in case of rapseed and sunflower plants.

The investigations conducted this year included exposure of vegetation to SO_2 concentrations simulating as closely as possible real conditions.

Constant background SO_2 concentration value of 0.2 mg/m^3 was maintained in the exposure chambers; apart from that the concentration was increased by 1 mg SO_2/m^3 for eight hours a day.

Only eight-hour peak values were subjected to neutralization. Table III shows the neutralization effect obtained for clover.

3. Study of the influence of ammonia flue gas neutralization products on the physio-chemical properties of selected soils.

After the first successful experiments with chemically pure products of neutralization the investigations are going to be continued this year.

The Environmental Protection Department of the Polish Academy of Sciences feels that it is justified to extend the research to the total balance of sulfur in the soil-plant-atmosphere system.

4. The influence of ammonia flue gas neutralization products on biological life in the waters.

Studies of the influence of flue gas neutralization by ammonia on biological life in the waters were carried out using reaction products obtained from real flue gas.

The reaction products of ammonia and real flue gas have had an effect similar to artifical fertilizers. In experiments conducted on fish appropriate doses of ash with ammonium sulfite have displayed no toxic action even after eight days of application.

5. The influence of ammonia flue gas neutralization products on the atmospheric corrosion processes.

Unexpected results were obtained in testing the influence of ammonia neutralized flue gases on atmospheric corrosion, even in the case of copper alloys. Table IV illustrates the extent of the protection giving brass type M-60 as an example.

Good results of all the preliminary experiments served as a basis for the design of a full scale experimental installation for two power sets of 260 MW total rating. The investigations carried out with the help of this installation were aimed at resolution of our doubts whether the remnants of fly ash particles passing through the electrostatic precipitator will not build up, gathering ammonium salts. Such a phenomenon might lead to considerable changes in the dust distribution in the vicinity of the power plant. Samples of dust contained in the plume were not different both for original flue gas and for the ammonia neutralized one. The measurements of the neutralization products spreading in the atmosphere made in different atmospheric conditions have shown that moist snow stimulates the greatest ammonium salt fall out.

The maximum fall out assumed for continuous neutralization over a period of one month and unvarying wind direction would result in 20 kg of ammonium fertilizer per hectare. It is less than doses used in agriculture.

The results described above were obtained in an installation neutralizing flue gas from boilers using bituminous coal of 2.5 to 3.5% sulfur content.

Similar experiments were carried out in Turow power plant in order to corroborate the results of tests for boilers using lignite. Fuel used in this power plant contains only 0.5% of sulfur, but as the calorific value of the lignite is low (2000 kcal/kg) the sulfur emission to the atmosphere is equal to about 1 t/hour per 200 MW set. The experimental installation permitted us to neutralize flue gas from a common stack for two power sets of 400 MW total rating. The longest period of neutralization run continuously was 11 days in weather conditions termed as "an autumn drizzle".

The good results obtained for this installation made it possible to plan the conceptual design of an experimental installation for an entire 2000 MW power plant. The problem to be solved, is what criteria should be applied to the start of intervention and its extent. There are two kinds of weather for which excessive SO_2 concentrations may occur in the lower layers of the atmosphere:

a. periods of little mobility of a large volume of air, with an inversion layer forming above the stack outlet level (a toxic cloud of SO_2 builds up over the power plant stack its base reaching ground level).

b. periods of considerable turbulence of the air layers near the ground occuring at relatively high wind velocities (whirls of poorly diluted flue gas "roll" on the ground).

Each of the types of weather described above will require different operation of the process.

Though the weather of the "a" type may be very dangerous for the biosphere it occurs rarely under our climatic conditions. The second type of weather occurs more often and the conditions created by it are responsible for the influence of SO_2 on vegetation in the neighborhood of individual sources of emission. The installation erected in Turow power plant will be equipped with a network of automatic SO_2 analyzers capable of monitoring the concentrations existing in the power plant vicinity. A special meteorological station located near the power plant will conduct an appropriate measurement program including all the meteorological parameters important for the distribution of pollutants in the boundary layers of the atmosphere.

The experience gathered during this research program should provide data permitting us to determine the intervention programs for individual power plants with less cost.

Our dry ammonia method which has been tested on a larger scale than other methods compares very well with these other methods from the economic point of view.

Taking into consideration the advantages of loss prevention in the forests and perhaps some fertilizing effect in agriculture and comparing them with the costs of interventional method operation it may turn out that the final economic balance is favorable.

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Table I

Selected examples of ammonia SO_2 neutralization protective action in case of the guinea pig

	healthy animals	poisoned animals		Diffe-rence	Student's "t" test	Diffe-rence	Student's "t" test
	m_1	SO_2 m_2	SO_2+NH_3 m_3	m_1-m_2		m_2-m_3	
Total albumen level in blood serum	6.98±0.2	5.90±0.4	6.50±0.45	1.08	12	0.60	5.0
Disturbance of acid-base equilibrium elements	45.7±9.5	53.0±8.5	45.3±5.68	7.3	2.35	7.7	1.6
Examples of electrolityc disturbances in blood serum	151±6.82	137.6±5.06	153.8±6.66	14.1	7.58	16.2	9.7

Table II

Protective influence of SO_2 neutralization by ammonia on rapeseed and sunflower

Type of Vegetation	Crop in grams			interval of confidence for $P = 0.05$	Relative values		
	0	SO_2	SO_2+NH_3		0	SO_2	SO_2+NH_3
Rapeseed	26.88	22.41	28.81	3.30	100	83.37	107.18
Sunflower	11.85	8.96	12.56	1.62	100	75.61	105.99

Table III

Influence of SO_2 neutralization by ammonia on clover

No.		Reference test	SO_2 background	SO_2 peak	SO_2+NH_3
1	Mean plant height /cm/	33.92	32.10	29.17	37.17
2	Dry mass /g/	27.39	27.06	20.51	30.80
3	Green mass /g/	134.91	137.51	105.01	142.25

Table IV

Corrosion of brass type M-60 in a chamber with SO_2 and with $SO_2 + NH_3$

Time of exposure	Mean loss of weight		Surface corrosion index V_c g/m^3 day	
	SO_2	SO_2+NH_3	SO_2	SO_2+NH_3
274	0.0046	0.0046	0.1775	0.178
521	0.0061	0.0051	0.124	0.103
825	0.0085	--	0.1094	--
969	0.0085	0.0066	0.091	0.070

AIR-POLLUTION PREVENTION AND CONTROL IN ROMANIA--GENERAL ASPECTS OF THE PROBLEM

By Matei Nicolau
Engineer, National Council for Science and Technology
Bucharest, Romania

It is known that nowadays the intensive rate of industrialization, urbanization, farming mechanization and the growth of transportation is bringing about in all countries an intensive air pollution problem which every day becomes more serious and raises particularly intricate problems from many a point of view such as: technical, economic, juridical, meteorological, biological and social-sanitary.

Air pollution effects can be reflected in the general health condition of the population, in the natural, biologic frame of the polluted area; in the service life of buildings; in plants, transportation means, and also in other material goods subjected to contaminants.

To improve the protection of the environment in Romania, a number of important steps have been initiated in an attempt to provide an organized solution for the present or future problems raised by air pollution.

Among these steps we may count the elaboration by the National Council for Science and Technology of a priority basic research program, the object of which is to devise new means and procedures for air pollution prevention and control so as to cope with the urgent character of the problem.

The main goals of the program are:

To maintain and improve the health condition of the population;

To reduce the damage produced in the national economy as a consequence of air pollution by implementing the research carried out on plants, tools, devices, and air pollution supervision, prevention and control systems;

To train specialized staff whose special task is to deal with problems related to air pollution prevention and control;

To develop and update the technical and material basis of the scientific research work carried out to improve the man-environment relationship;

To develop and expand at an international level, technical and scientific cooperative efforts for solving problems related to clean air; and

To inform and educate the population with a view of stimulating its participation in the general effort.

The priority program of scientific research aims at air pollution prevention and control and is to be given life through well defined actions closely related to present and prospective needs of the Romanian economy.

This program carries on scientific research work on air pollution and environmental protection initiated during the last years by a number of research institutes and specialized centers working in the field of chemical engineering, metallurgy, electrical engineering, and the building material, food, and consumer goods industries. This research has resulted in the design and building of efficient plants, equipment, aggregates and facilities dedicated to air pollution supervision, prevention and control.

The scientific research work included in the program is centered on problems of a technical, economic, juridical, meteorological and social-sanitary character.

Among these problems, we mention:

Cleaning of hot gases containing suspended particles;

Cleaning of industrial sulphurous anhydride gases;

Desulphuration of liquid and solid fuels;

Improvement of processes applied for dry cooling of incandescent coke in ferrous metallurgical works;

Smokeless charging of metallurgical coke furnaces;

Cleaning of hydrogen sulphide from industrial gases;

Fluorine trapping and recovery in super-phosphate and aluminium production works;

Catalytic burning of residual gases generated by petrochemical refinery plants;

Trapping and cleaning of residual gases generated by works producing carbon black;

Cleaning of noxious gases evolved by technological processes applied for metal surface coating;

Cleaning of odorant gases;

Cleaning of gases evolved from lead and zinc producing processes and recovery of non-ferrous metals from these gases;

Cleaning of gases discharged by motor-cars;

Dust trapping in foundries, ore processing plants, coal preparation plants, refractory and building material production factories, ore sintering plants, etc.;

Establishment of quality characteristics for the environment in various areas and working sites;

Effects of contaminants on environment quality and permissible limits for their action;

Establishment of air self-cleaning parameters;

Improving understanding of turbulent diffusion of contaminant gases by the atmosphere;

Recovery of useful substance from industrial residual gases;

Study of noxious effects of contaminants on the natural biological environment; and

Studies of the effects of environment pollution on the human organism.

In addition to these missions of a scientific character, an important concern is also felt in Romania for the organizational and quality control aspects of the air pollution problem.

Thus the big contaminant producers(i.e. industrial plants and aggregate works) have been required by the rules in force to revise their gas cleaning plants and their waste plants, and to improve their plants with a view to avoiding air pollution exceeding the limits adopted.

Staff training and specialization in problems related to the atmospheric environment are to be taken care of within the priority research program already mentioned. Thus, staff training and specialization programs will include both postgraduate training courses organized within the frame of high technical institutes, and refresher courses held within specialized research organizations.

In parallel with the efforts for staff education and specialization, the organizational steps recommended for environment protection in Romania include important actions involving education, information and active and wide participation of the population to air-pollution control.

Education of the population takes the form of training on general and town hygiene and on the bases of technical and sanitary education in the framework of secondary education.

The education of the population in the field of air pollution protection will be carried out in the people's universities, as well as through periodically organized lectures and symposia, particularly within large industries and urban centres.

The laws in force on hygiene and public health have educational character and, as a consequence, the efforts displayed by our government for the protection of the atmospheric environment results in a wide participation of the population. The population of our countries is well informed of the causes and effects of air pollution and of the latest achievements of scientific and technological research carried out on the supervision, prevention and control of environmental degradation, both in Romania and abroad.

Radio and television broadcasts are always available to those responsible for public information about environmental protection. At comparatively short time intervals, special programs are broadcast through these channels, describing the main technical, economic and sanitary aspects of our air pollution control program in the context of the intensive industrialization under way in our country.

Moreover, the press devotes a large amount of space in the newspapers to problems related to environmental protection and, through a number of scientific and technical journals and wide circulation, the latest news in this field is widely disseminated.

We feel that the strong actions now in full progress in our country directed toward air protection, favoured by a wide participation of the population and of an important number of central and local state, economic, scientific and public organizations, are in full accord with the goals of the U.N. which includes this problem among its most urgent concerns.

At the same time, these actions set up the basis for wide cooperation with the technical, economic and scientific efforts of all countries concerned by this problem, the United States of America included.

BASIC CRITERIA OF THE NORMS FOR MAXIMUM ADMISSIBLE POLLUTANT CONCENTRATION IN THE ATMOSPHERE OF TOWN AREAS

By M. Barnea
Head of Laboratory
Institute of Hygiene and Public Health
Academy of Medical Sciences
Bucharest, Romania

It is known today, on theoretical and practical bases, that to obtain good results in the protection of the atmosphere and to avoid the deleterious effects of pollution, it is necessary to apply quantification methods, useful for appraising the effects of pollution and the efficacy of the measures taken for controlling pollution. General concensus exists concerning the use of limits on pollutant levels in the atmosphere of town districts as a basis for pollution control.

The complexity of the phenomena involved in air pollution is one of the main causes of the delay with which the norms of protection based upon maximum admissible concentrations are being drawn up, in spite of the importance attributed to this problem throughout the world. Another cause of delay is the absence of a unitary concept of the principles for establishing thresholds of damage.

A generally accepted criterion, substantiating pollution control measures, is the pathologic effect upon humans and upon animal organisms in general. Numerous proofs of toxic risks have been made evident in the form of acute diseases and even of deaths, or by an increase in chronic morbidity.

Local, regional and worldwide econologic hazards, that may have indirect implications upon the health of humanity, may likewise represent important reference points for the orientation of control methods. An instance of a mechanism of action of this kind is the hypothetical consequence of a change in the natural radiant regime and consequently in the earth's climate, with harmful effects upon human society in its entirety, caused by pollutants considered until lately as almost harmless--carbon dioxide and non-toxic dusts, in apparently anodyne concentrations but generalized throughout the atmospheric ocean. Another instance is the action of substances with deleterious properties, such as carcinogenic hydrocarbons, heavy metals, radioactive substances, etc.

For the human society of today and of the future, the effects upon the biosphere may be of primordial importance, such as the degradation of artificial, lifeless structures, for instance that caused by corrosion, especially when they affect the fine mechanisms of complex automatic machines, computers, etc.

Of all the effects of pollution, those that affect the health of mankind must be considered the most important. In most cases, on adopting the thresholds of action upon man as reference points of protection, a benefit is also incurred in other sectors. Mixed public health and economic considerations are sometimes taken into consideration in establishing norms of protection.

The health criteria of pollutant norms and air purity indices, accepted in 1964 by the W.H.O. Committee of Experts (Technical Reports Series no. 271) is an oustanding guide in this connection.

1. The basic criteria of air purity indices are the tests according to which the order of magnitude of the effects of air pollution on man and his environment can be determined.

2. Air purity indices indicate the concentrations and duration of exposure corresponding to the specific effects that various degrees of air pollution may have on humanity, animals, plants and the general environment.

3. At the present level of our knowledge, air purity indices may be defined by four categories of concentrations, duration of exposure and corresponding effects. These four categories are characterized by limit values that may vary for a given pollutant in terms of the effect taken into consideration, the criteria applied, the nature of the other substances present and the meteorological factors, also taking account of the diversity of reactions in different groups of people. The participants to the W.H.O. Symposium agreed to define the four categories by the following levels:

Level I. The concentration and duration of exposure are equal to or less than the values which, as far as we know, have no direct or indirect effect, including change in the reflexes or in the modification of protective reactions.

Level II. The concentration and duration of exposure are equal to or greater than the values at which irritation to the sense organs, noxious effects upon the vegetation, reduced visibility or other unfavorable effects upon the environment, may be noted.

Level III. The concentration and duration of exposure are equal to or greater than the values at which impairment or alteration of vital physiologic functions that risk production of chronic disease or premature death, probably take place.

Level IV. The concentration and duration of exposure are equal to or greater than the values at which an acute or chronic disease, or premature death would probably occur among vulnerable groups of the population.

The W.H.O. Committee expressed the wish to establish without delay international indices of the purity of the air, on the basis of these principles.

However, these levels recommended by the Committee at present, do not define an admissible limit. Rather, they emphasize air pollution by deleterious biologic substances that result from man's activity should be avoided as much as possible.

The fact that no precise criterion has been adopted by the Committee in its recommendations and that the introduction of norms of maximum admissible concentration into practice have encountered many difficulties and have differed from one country to another, shows that at present no readily applicable method exists for the drawing up of air protection norms.

The generally accepted criterion, thatof acute or chronic disease, is not fully satisfactory from the viewpoint of hygiene, since a series of changes in the health status may develop before they manifest pathologic symptoms, which, once they have set in, may be irreversible. Correct prevention implies evidence of preclinical changes, and no general consensus exists concerning them. The utility of certain indicators of preclinical alterations is also demonstrated by the high morbidity rate attributed to pollution by epidemiologic studies carried out in zones of moderate pollution. It is hard to confirm these effects experimentally because of the infinite difficulty of reproducing in animals the complex situation in which a population lives in a polluted area. The duration of the action upon humans cannot be realized with animals and the response of man is different from that of animals, etc.

Moreover, in order to establish the threshold and mode of action of air pollutants a great number of experimental variants are necessary, involving single substances and mixtures, in combinations in which various aspects, linked to organic or environmental-dependent adjuvant factors, interfere.

On putting into concrete form the norms of maximum admissible concentrations, an important contribution would be to quantitatively correlate the results of epidemiologic studies with the concentration of pollutants in the air. On the basis of correlations heretofore established, it was possible to determine the role of mean concentrations over a long interval (one year or more) at particularly low values (for instance, non-toxic particles and mean sulfur dioxide concentrations of tenths of milligrams). Such results were found in air basins with well known pollution, where morbidity from respiratory disease is high, as for instance in certain industrial regions in England and U.S.A. This has led the bodies responsible for drawing up protection norms to take epidemiologic criteria (well conceived, and applied in terms of long duration, medium concentrations) into consideration. This procedure must be complemented by, and be in agreement with, short duration concentration norms--1 month, 1 day, 8 hours, 30 or even 5 minutes. As shown by Stern and other authors, a long duration medium concentration also includes larger concentrations, in a smaller and smaller proportion of cases. The norms of maximum admissible levels previously elaborated refer in most cases to short intervals of 24 hours and 30 minutes. Complete norms should keep account of a wide range of values, establishing the maximum admissible concentrations for all time intervals. For a single time interval the special properties of the respective substance must be borne in mind. For instance, with substances that act by an acute mechanism, such as most toxic irritants which have an effect upon the nervous system, short term norms should not be overlooked. For substances that act by accumulation, such as heavy metals, chronic effects and mean levels over a long term (a year or more) must be taken into consideration.

It is recommended that mathematical methods be applied, at least for extrapolation. It appears pertinent that these methods may have to be adapted to the physiochemical properties of the respective substance. Countless variants are necessary to confront the experimental results with reality, and these could only be covered by broad international cooperation. A foremost impediment is the multiple standard conditions under which experimental investigations have to be carried out.

A difficult question concerning which there is no general agreement is that of the threshold of noxious action. According to some workers this threshold is exceeded only when a lesion or signs of disease appear; according to others it is sufficient to note alteration of certain important functions, representing the preliminary phase of the lesion or of the disease. Although the two opinions seem divergent, some of the results converge towards maximum admissible concentration values. Practice has shown that for the sake of safety it is necessary to adopt lower values of the norms. It seems more difficult to reach an agreement concerning substances with an exceptionally low olfactory threshold, for which this property alone is considered a reference point for substantiating the norms of maximum admissible levels. This viewpoint has not been accepted by all authors.

From our experiments, we find that, in order to establish threshold effects, it is useful to carry out complex investigations on the four categories of functions which have an important role in the reaction of the organism to air pollution:

-metabolic (e.g. body weight curve and oxygen consumption);

-neurologic (motor and optic chronaxie, conditioned reflexes, adaptometry and electroencephalography);

-enzymologic (especially blood catalase and hepatic enzymes--transaminase, aldolase, succindehydrogenase);

-immunologic (resistance to infection and antibody genesis).

In some cases it is necessary to investigate other systems as well, especially the blood (morphology of the white and red cells, proteinemia, etc.).

For many toxic substances, it is recommended that the loading of the body with the respective toxic substance or its metabolites be determined by biochemical, histochemical and other methods. For this type of investigation, it is necessary to establish corporeal loading norms for the healthy subject; and here, too, there is no general agreement.

As a rule, in order to establish the deleterious effects of experimental pollution at threshold and higher toxic doses, it is recommended that a complex set of investigations concerning general reactions on the one hand and specific responses on the other be carried out. The results should be interpreted complexly taking into account the several reactions at the same toxic level.

The experimental models by means of which the deleterious effects of air pollution are studied are closer to reality when the combined effects of two or more toxic substances are investigated, and when the physical and biologic parameters of the experiment are varied. We obtain good results in our experiments by determining the separate and combined actions of the toxic metals Cl ± SO_2± Pb.

Selection of the tests and interpretation of the changes produced are of paramount importance in establishing the standards of maximum admissible concentrations. The results of our experiments are interpreted in comparison to the behavior of controls, by calculating the statistically significant differences for as great a number of tests as possible. The results of one of a few positive tests (in terms of their importance) are considered insufficient to establish thresholds of deleterious effects or norms of maximum admissible levels.

It is recommended that tests on animals be complemented by tests on humans, especially when the risk of threshold doses is minimal.

However, the results of these investigations are only partial if we bear in mind the prolonged and complex action of pollutants in town districts. Therefore useful conclusions, closer to the actual facts, should be obtained by epidemiologic study of the complex statistical changes brought about by pollution among the population constantly exposed to certain pollutants, under the concrete conditions of populated centers. For this purpose it is necessary to study under separate conditions the phenomena that interest us; especially to exclude toxicomania and occupational intoxication as interfering factors and to select carefully the subjects exposed for a long time to atmospheric pollution. In establishing the norms of maximum admissible levels, it is obligatory that we determine air pollution systematically in the area where the population whose health status we are studying lives, and as mentioned previously, calculate the mean values over varied intervals of time. We also must use adequately chosen controls. In our epidemiologic investigations, in the absence of biologic norms for healthy subjects, we use as controls, results obtained in similar groups of people living in pollution-free areas.

As the conditions required by such investigations are seldom found in the field, the results can only be considered as partial. However, conclusions may be confirmed by the investigations other researchers working under similar or nearly similar conditions elsewhere. Particularly interesting in this connection are the reports and graphical representations drawn up by D.H.E.W. in the U.S.A. referring to sulphur oxides and other pollutants.

Practice has shown that although the possibilities of substantiating maximum admissible air pollutant levels are reduced, it is necessary to develop and apply provisional legal norms, and to use as low values as possible.

THE ACTION OF ATMOSPHERIC DUST AND GAS POLLUTANTS ON INFECTIOUS PROCESSES

By Ilie Ardelean
Professor, Corresponding Member of the Academy
of the Socialist Republic of Romania
Head of General Hygiene Chair
Medicine and Pharmacy Institute
Bucharest, Romania

Investigations Concerning the Action of Dusts and Gases on Infections of the Respiratory Tract

In studies concerning the effect of polluted air on infectious processes, increasing emphasis is laid on the important role played by pollutants in the increase of morbidity from respiratory infections. Foremost of all are the statistical investigations regarding the relationships between the incidence of chronic bronchitis and the level of air pollution. In this connection recent statistical studies have shown a marked rise in the incidence of chronic bronchitis and the frequency of acute attacks of the disease in the towns with polluted air, the correlation being established especially with sulphur products and dusts in the air. At present, air pollution with irritating substances is considered, next to smoking, one of the main etiologic factors in chronic obstructive bronchitis. Similarly, an increase was found in the frequency of acute infections of the respiratory tract. Douglas and Waller found a close relationship in children between deep respiratory infections and the level of air pollution. Curtis Dohan found an evident correlation between morbidity from respiratory infections and the concentration of sulfur compounds in 8 towns in the United States, with various levels of pollution. Among the diseases which can be correlated to air pollution he mentions influenza and other viral respiratory diseases.

In Romania the statistical investigations carried out show a correlation between the degree of air pollution in populated centers and the incidence of acute and chronic diseases of the respiratory tract.

Our studies, started in 1960, have been carried out under experimental conditions, and have concerned the action of various dusts (silicon dioxide, coal and calcium carbonate) and gases (sulfur dioxide and chlorine) on infectious processes (pneumococcus and influenza virus).

The Action of Silicon Dioxide, Coal and Calcium Carbonate on Pneumococcal Infection

The size of the silicon dioxide particles used in the experiment was 90.5% less than 5 μ; 6.5% between 5-10 μ; 2%--10-20 μ; 1% over 20 μ; that of calcium carbonate 88% less than 5 μ; 7%--5-10 μ; 2%--10-20 μ; and 3% over 20 μ; that of coal particles was 73% less than 5 μ; 14%--5-10 μ; 6%--10-20 μ; and 7% over 20 μ.

As the pathogenic agent was used a pneumococcal strain, type XIX. The dusts were mixed in 0.5 mg amounts together with different pneumococcus dilutions, and administered to mice by intraperitoneal, subcutaneous and nasal routes.

Intraperitoneal administration of the silicon dioxide mixture gave a mortality rate of 61.5%, the coal mixture 61.5% and calcium carbonate 50.0%, as against a mortality rate of 44.9% in the control lot.

Following subcutaneous inoculation, the mortality rate in the experimental lot receiving silicon dioxide was of 93.7%; in the lot with coal 89.6%; and in that with calcium carbonate 83.3%; as against 58.3% recorded in all the animals of the control lot.

In the lots inoculated by the nasal route, a higher mortality rate was found in the lot receiving silicon dioxide, i.e. 31.1%, and in the lots with coal and calcium carbonate 33.9%, than in the control lot 21.4%. The anatomic lesions in the lungs of the mice sacrificed 10 days after inoculation were far more extensive and frequent that in the control lot.

The Action of Dusts on Experimental Influenza Infection

Influenza virus, strain PR8, together with the silicon dioxide, coal and calcium carbonate dusts, administered by the nasal route under the same conditions as pneumococcus gave a mortality rate of 80.5% in the group receiving coal, of 75% in that with silicon dioxide and of 73.6% in that with calcium carbonate, as compared to 45.8% in the control lot.

No differences were noted between the extent and frequency of the lesions of influenza pneumonic type in the dead mice of the lots receiving the dusts tested and those of the control lot. However, there was a sharp difference between these lots and the mice sacrificed 12 days after inoculation. The lot receiving silicon dioxide exhibited pulmonary condensations in 55.5% of the cases, that receiving coal in 28.5%, and the lot with calcium carbonate 26.3%, as against 17.9% in the control lot.

These results show that dusts, and especially silicon dioxide aggravate experimental influenza and result in prolonged forms of the disease.

Lowered Resistance to Infection Due to Chronic Sulfur Dioxide Intoxication

Mice were kept in a sulfur dioxide atmosphere for 6 hours a day, during 106 days. Average sulfur dioxide levels in the air circulating through the pollution chamber was of 16-28 mg/m^3. After this period the animals received an infectious pneumococcus XIX dose my intranasal route.

The pathologic process was influenced by the action of sulfur dioxide, the frequency of pulmonary condensations being higher and the tendency to lengthening of the infectious evolution more marked.

The Action of Low Chlorine Concentrations on Experimental Influenza Infection

Investigations were carried out concerning the action of chlorine on influenza in mice exposed for 21 days, during 7 hours a day in the intoxication chamber, to a concentration of 4.0 mg of gaseous chlorine/m^3 of air. After the intoxication period the mice received an influenza virus PR8 suspension by the intranasal route.

The mortality rate in the intoxicated lot was of 42.6% as compared to 21.6% in the control lot. Similarly, the influenza pulmonary lesions in the animals sacrificed 12 days after inoculation were more frequent, i.e. 77.4% in the lot exposed to chlorine and 20.7% in the control lot.

It may be concluded from the results of our experiments that pollutants influence the respiratory infectious process to various degrees in terms of the physiochemical characteristics of the dust or gas. Under the influence of these agents, morbidity from pneumococcal or influenza infections increase in the experimental animals, producing a greater number of pneumonic lesions.

Experimental Investigations on the Phagocytosis Capacity and Bactericidal Activity of Leukocytes in the Presence of Dust Pollutants

Starting from the pathogenic mechanism of pneumoconiosis, and especially silicosis, in which fibrosis is the result of complex cellular and humoral reactions to the toxic action of dust, we attempt to develop an *in vitro* method by means of which it would be possible to determine the toxicity of these physicochemical agents. The principle used was testing of the phagocytic activity of leukocytes.

The phagocytic test, or microcinematography, consists in the injection of a dust suspension in the peritoneal cavity of an experimental animal, preferable a rat. Within a few hours the injection induces an afflux of mobile cells--leukocytes--that phagocytize the dust particles. At this time, collection from the peritoneal cavity content and examination of the vital preparation in the microscope, under accurately defined optical conditions, will reveal the influence of the dust on the behavior of the cell, especially the migrations and movements within the cytoplasm. It thus becomes possible to study the behavioral and structural changes that take place in the phagocyte.

The general condition for applying the test is to use very small dust particles. Particles larger than 5 μ cause a special reaction, known as a "foreign body reaction", i.e. the large particles cannot be ingested by a single cell but only by several cells which cluster together forming a giant cell. This phenomenon is produced both by inocucous and by noxious dusts. Because of this, these tests should be carried out with dust particles measuring 3-5 μ.

The dust phagocytosis test was applied by us in a more complex way, since we considered that the toxic action of dust particles on the cytoplasm of polynuclear leukocytes--the main defense elements of the organism--may be established not only directly by measuring changes produced in the cell, but also indirectly by measuring the reaction potential of the phagocytic system, blood cells and plasma to microbes, after their prior contact with the dust particles. Otherwise stated, we tried to determine the phagocytic and bactericidal complimentary capacity of the blood after being subjected experimentally to the toxic effect of dusts.

This method and technique, introduced by us, permits both a qualitative and a quantitative appraisal of the influence of dusts on the phagocytic system.

Human blood obtained by venous puncture, and from animals by cardiac puncture, is defibrinated by stirring, or prevented from coagulating by adding heparin. In order to raise the number of blood leukocytes up to 5,000, 10,000 or 20,000/mm^3, pure leukocytic exudates are prepared in the peritoneal cavity of the rabbit by twice injecting 150-200 ml normal saline within the cavity. After the second injection the peritoneal exudate is collected in a 1.5% sodium citrate solution. The concentration of the leukocytes is determined and then the mass of centrifuged leukocytes is added to the defibrinated blood and adjusted to the respective concentration per mm^3 blood.

The microbial suspension is prepared from young cultures in a fluid medium, washed by centrifugation and suspended in simple broth so as to obtain approximately 100 million microbes/ml. A o.1 ml amount of the microorganism emulsion, in a dilution of 10^{-1} to 10^{-6} is distributed into each glass vial, together with 10 mg of dust. SiO_2 and C granulometry showed a dispersion of 95% below 5 μ. The dust was first put in contact with the phagocytic system, and after 30 minutes the microorganisms were added. The vials with the accurately measured ingredients are fixed in a rotating device, at 37°C. The phagocytic index and bactericidal activity were determined at 10 and 30 minutes, 2, 6 and 24 hours.

The phagocytic index was calculated on the one hand, by determining how many of 100 leukocytes ingested microorganisms, and, on the other hand by counting the number of microorganisms ingested per 100 leukocytes. At the same time, the number of non-ingested microorganisms was counted in 10 microscopic fields and marked ± up to +++, according to the number of 1-10 microorganisms outside the leukocytes in one field.

The bactericidal index was calculated by the total number of colonies that developed in a blood gelose medium poured into dishes and inoculated with a standard bacteriological loop with a blood+leukocyte_dust_microorganism.

Here are some of the results obtained with SiO_2, C and calcium carbonate, using as control a normal saline solution and immune serum against by respective microorganism, in this instance pneumococcal antiserum.

Results

1. Immune serum. Very intense phagocytosis, with rapid digestion of the pneumococci. Phagocytic index was 35% at 30 min. There were no non-phagocyted pneumococci. The bactericidal activity of the system was very marked: at 6 h, no pneumococcus cultivated from 1 mm^3 blood.

2. Normal saline. High intensity of phagocytosis, with a phagocytic index of 35% but with prolonged digestion of the pneumococci as compared to the immune serum samples. Bactericidal activity of the leukocytes was of medium intensity: at 6 h, 50 pneumococci developed on 1 mm^3 blood; and at 25 h, 100 pneumococci developed.

3. SiO_2. Phagocytosis of low intensity. Phagocytic index was 22% after 30 min. contact with SiO_2 dust and pneumococci, and remained low at 6 h. It increased to only 41% at 24 hours, when the non-phagocyted pneumococci began to multiply. Bactericidal activity was close to but less than, that of the normal saline samples at 6 h. At 24 h the number of pneumococci increased to 11,000 per mm^3 blood.

These results show that silicon dioxide particles inhibit the phagocytosis and bactericidal activity of leukocytes, without definite action upon the viability or multiplication of the pneumococci.

4. Coal. Coal particles produce a powerful phagocytic action, the phagocytic index at 30 min. being 44%, is still high at 6 hours, and attains 80% at 24 h. Outside the leukocytes at 24 h there were a large number of non-phagocyted leukocytes, whose number was of the order of dozens of pneumococci on the single microscopic field. Although the bactericidal activity of the leukocytes was not inhibited by the coal particles, owing to multiplication of the pneumococci in the system, there were a large number of live pneumococci--at 6 h 600 pneumococci being counted; and at 24 h 200,000/mm^3 blood.

Therefore, coal particles are considered inert and, with little effect upon the leukocytes, favor the multiplication of pneumococci.

5. Calcium carbonate has an effect similar to that of coal, the phagocytosis index of 30 min. being 32%, but not exceeding 50% at 24 h, so that a large number of pneumococci are found in the system. The leukocytes that ingest calcium carbonate crystals have a hyaline aspect and phagocyte pneumococci to a small extent. Leukocyte bactericidal activity, appraisable at first, i.e. 500 microorganism cultivated at 6 h falls sharply at 24 h, the number of pneumococci reaching 1 million/mm^3 blood.

Calcium carbonate strongly favors the development of pneumococci.

Conclusion

The results obtained with this experimental model supply data that confirm the conclusions obtained in experiments on animals. Dust particles, even those considered as slightly toxic or inert, aggravate the infectious process.

AIR POLLUTION CONTROL ON THE WORKING PLATFORMS OF COAL CARBONIZATION PLANTS

By Matei Nicolau, Engineer
National Council for Science and Technology
Bucharest, Romania

On the coal carbonization installations of siderurgical combines, three types of technological processes have been evidenced which cause air pollution. These processes directly affect the working platforms of the coking batteries, as well as the surrounding zones.

In decreasing order of their noxious potential, these technological processes are:

Lateral charging of the coal blocks into the pyrogenation chambers of the coking batteries;

Quenching the incandescent coke; and

Tar removal from the raw coke gas collectors.

Besides pollution generated by the above three technological processes, the coking battery working platforms are polluted also by other air pollution sources, for instance during discharging the coke mass from the oven, or during transport of the incandescent coke, etc.

The present paper contains some contributions to the problem of fighting air pollution on the working platforms of coking batteries, in connection with the above-mentioned three technological processes, causing pollution of the surrounding atmosphere.

Technological Process of Charging the Coal Blocks into the Coking Battery Chambers

The technological process of charging the coal block into the coking battery chambers may be performed either over the top of the coking battery, or laterally, on the side of the charging machine.

The technological coal charging process over the tope of the coking batteries is accomplished in "loose" charges, for which only high quality coking coal can be used.

This charging operation of the coal into the coking oven may be performed without the generation of raw coke gas. Therefore this process is known as "smokeless charging of coal pyrogenation ovens."

Smokeless charging of coking ovens is performed frequently with the aid of a charging machine, traveling on the top of the coking battery, and with the aid of raw coke gas collecting and purification installations, using various hydromechanical systems.

Unlike the charging of the coking battery from the top, lateral charging of the coal pyrogenation chambers--common to many coking plants throughout the world--is achieved with the aid of compacted charges, while raw coke gas is generated right during the introduction of the coal block into the oven, through a degassing process of the coal in contact with the incandescent walls of the oven.

Evacuation of these gases from the oven during the coal block charging operation is achieved the natural way, both through vertical discharge flues provided in the roof of the coking battery, and as well through the interstices created between the coal block and the walls of the oven, which are about 1.2--1.5 mm wide between coal block and side walls, and about 4--5 mm wide between the upper face of the coal block and the roof of the pyrogenation chambers. These raw coke gases, with a pronounced cancerigeneious character flood the working space of the charging machine and the upper coking battery platform, creating--on the one side--extremely hard working conditions for the coking plant workers--and on the the other side--causing severe pollution of the atmosphere of the siderurgical combine, as well as of the entire environments outside the combine, up to a distance of 1--2 km.

The main difficulty encountered by the smokeless lateral charging of the coal block into the coking chambers is primarily due to the fact that any mechanical equipment connected to the vertical flues for the evacuation of the raw coke gas, will create under-pressure operating conditions in the interstices between coal block and roof of the oven.

This under-pressure condition facilitates the influx of an important amount of fresh air into the plant, which, when mixed in certain proportions with the raw coke gas, will cause an explosion hazard.

However recent investigations in this field have revealed the possibility of solving the lateral smokeless charging problem of coking batteries, but up to the present, no optimum solution, both from the point of view of air pollution control, as well as from the point of view of economic requirements (minimum investments and low operating costs), and of the possibility of integral recovery of the raw coke gas, has yet been elaborated.

Nevertheless, among some of the solutions suggested for the smokeless lateral charging of coking batteries, the following solutions may be taken into consideration:

Blowing the raw coke gas into an additional collector with the aid of a steam ejector;

Blowing the raw coke gas into the regular collector, also with the aid of steam ejector;

Blowing the raw coke gas into a neighboring oven, where the pyrogenation process is yet incomplete;

Burning the raw coke gas in a vertical fire chamber, built in the shape of a Laval nozzle, where the raw coke gas is moved with the aid of a central steam jet under a pressure of 10--12 atms; and

Natural evacuation of the raw coke gas into the atmosphere through the aid of specially designed stacks placed on the top of each vertical flue on the upper coking battery platform.

The Technological Process of Quenching the Incandescent Coke

The second main problem deriving from the coal carboinzation technology, causing pollution of the coking battery working platforms, is the quenching of the incandescent coke.

The quenching of the incandescent coke in a siderurgical plant presents two separate aspects:

One connected with the pollution of the atmosphere; and

An important economic aspect.

Under the conditions of conventional coke quenching, the incandescent coke delivered from the coking batteries into trucks, is hauled to the chilling tower, where the quenching operation takes place.

The quenching operation is performed with the aid of phenol containing water resulting from technological processes in the chemical plant, through direct contact between coke and water.

After cooling, the quenching water is collected in a pit, from which it is recirculated into the quenching installation.

The quenched coke is transported to the drying platform from which it is taken to the sorting selection by means of belt conveyors, and then shipped to the various users (blast furnaces, steel plants, mineral agglomeration plants, etc.).

It is well known that 4 cubic meters of cooling water are required for the quenching of each ton of incandescent coke.

During the cooling process of the coke about 0.8 m^3 of phenol containing water for each ton of coke goes into the atmosphere of the plant, as vapors.

These phenol containing vapors posess cancerigeneous properties, and through their settling-down on the surface of the ground, they produce noxification of the coking plant environment, as well as of the entire surroundings of the mill.

Moreover, during cold weather, these vapors impede visibility on the working site of the plant, which may cause traffic accidents within the area of the mill.

On the other hand, through evaporation of residual phenol bearing water particles from the quenched coke, a foggy atmosphere is created around the coking batteries, particularly on the final coke cooling platform.

These vapors on the final coke cooling platform, resulting from residual particles of phenol bearing quenching water, pollute the atmosphere to a particularly high degree, reducing the visibility in the working area of the coke handling machine and in the zone of the railway track situated between the coking battery platform and the final cooling platform to zero.

Besides these serious inconveniences, the pollution of the atmosphere in this area, through the noxious character of the cancerigeneous vapors emanated, represents a serious hazard to the health and life of the workers employed in the operation of the coking batteries.

At the same time with the above social and sanitary inconveniences, the coke quenching process also presents a serious economic disadvantage because it facilitates dissipation into the atmosphere of the physical heat of the incandescent coke.

Owing to all these disadvantages presented by the coke quenching method, it appears necessary to realize a dry cooling method for incandescent metallurgical coke.

The technological process of dry cooling incandescent coke eliminates air pollution and, as compared to the conventional coke quenching method, presents two important economic advantages, i.e.:

The possibility of recovering the physical heat of the incandescent coke subjected to cooling; and

Qualitative improvement of the cooled coke.

Dry cooling of the coke is achieved with the aid of inert gases (as N_2,CO_2, etc.), resulting from the combustion of a very small percentage of the incandescent coke charge placed in the cooling trough.

By shutting down the admission of air into the cooling trough, the combustion process is interrupted, while the remaining combustion gases, now inert, are recirculated in a closed circuit over the charge of incandescent coke in the trough. Thus they gradually take over the physical heat of the coke, delivering it in turn, in a heat exchanger, to the inert gas cooling agent, for instance water, which is transformed to superheated water, saturated or superheated steam.

Through recovery of the physical heat of the incandescent coke, a minimum amount of at least 400 kgs of steam per ton of cooled coke may be obtained.

With regard to the improvement of the qualitative properties of the coke through dry cooling, it should be mentioned that the water content of the coke decreases while the heat output increases.

Due to the slow cooling process of the coke, through dry cooling, the possibility of the formation of internal stresses in the coke is eliminated.

Dry cooling of the coke results in a more uniform coke grain size and in a higher mechanical strength of the coke.

Owing to the multiple economic and social-sanitary advantages presented by the dry cooling method, as compared with conventional quenching methods, investigation of this new process has appeared necessary in recent years in the scientific research programs of specialized research institutes in the S.R. of Romania, with encouraging theoretical and practical results.

The world over, the dry cooling of the coke is accomplished through the use of inert gases (N_2, CO_2, etc.), while the recovery of the physical heat of the incandescent coke is achieved by passing the gas which has flowed over the coke charge to be cooled, through a heat exchanger, through which a cooling agent, for instance water, is circulated.

During recirculation of the hot inert gases through the heat exchanger system, particles of non-combustible mineral substances and coke particles entrained by the inert gas, settle down on the surfaces of the heat exchanger thus impeding efficient heat transfer between the cooled agent (inert gas) and the heated agent (water).

Another disadvantage presented by known dry coke cooling methods, the rapid deterioration of the heat exchanger system and premature breakdown of the inert gas recirculation equipment is also due to dust particles entrained by the hot inert gas.

Solutions, proposed in Romanian patents, eliminate the above disadvantages by first cleaning the hot inert gas before it enters the heat transfer system.

The Technological Process of Tar Removal from the Raw Coke Gas Collectors

The third air pollution problem of importance on the working platform zones of coking batteries consists of removing tars from the raw coke gas collectors.

For the chemical and energetic utilization of the raw coke gas produced by the coal pyrogenation process, these gases are collected with the aid of a collector placed on each coking battery.

During the coal carbonization process, the raw coke gas generated contains, besides other components, water and tar vapors, which partially settle out in the collector as condensed matter. Moreover, these gases, while traversing the charge, entrain small size coke particles (under 15 mm in size), which together with the condensed tar acting as a binder form agglomerate deposits (coke dust and tar), called tar mass, which settle out in the raw gas collector.

Repeated deposition of tar masses, without their routine removal, may lead to the plugging of the raw coke gas collector, constituting an important problem in the operation of coal pyrogenation plants.

At present, at some coking plants, the removal of tar masses deposited on the inner walls of the raw coke gas collector is achieved manually with the aid of steel bars introduced through the collector inspection holes. These inspection holes are provided on the upper side of the collector and are placed at intervals of about 1000 mm from each other.

Owing to the fact that inside the raw coke gas collector there exists an overpressure (of about 6--12 mm water column), during the removal of the tar mass from the inner walls of the collector, raw coke gas discharges through the inspection holes into the atmosphere, causing intense air pollution in this zone of activity.

This problem has not yet found an optimum solution on a worldwide scale.

The removal of tar masses from raw coke gas collectors has been attempted with the aid of ammonia-containing water under pressure (20--25 atms), but this procedure has not lead to the results anticipated, because under the usual operating conditions, a stable emulsion is formed between the tar and the ammonia-containing water. The components of this emulsion are very difficult to separate by conventional means (settling out, etc.). On the other hand, the process requires considerable energy which results in increased coking plant operating costs.

Taking into account the inconvenience presented by the hydraulic ammonia-water method for removing tar masses from raw coke gas collectors, it is evident that for an optimum solution of this problem, other methods have to be found.

Treatment of the problem through a purely thermal method, by adoption of a tar and tar mass removal procedure using steam jets, does not reveal positive prospects for solution of the problem, because of the following disadvantages:

Owing to the thermal operating regime of the collector, at a temperature of below 95°C, the steam introduced will condense, thus the entire problem is reduced to the above-mentioned hydraulic method using ammonia containing water; and

Owing to the overpressure created by the water vapors inside the collector, these vapors may penetrate into the coal charge to be carbonized, thus prejudicing the pyrogenation process.

A sealed mechanical collector, tar cleaning and removing system cannot be considered because of the difficulty of cleaning such mechanical systems.

Thus, taking into account the above considerations, an optimum installation leading to the solution of the problem must fulfill the following conditions:

It must achieve efficient cleaning of the tar masses and tars and their optimum removal from the raw coke gas collector, while maintaining perfect tightness of the entire system.

It should use an auxiliary fluid medium, circulating through the collector, and which should be easily recoverable. It is to be mentioned that raw coke gas and "condensate", are circulating through the collector. This condensate contains tar, water and coke particles. The tar derives from condensed tar fumes contained in the raw coke gas while water comes partially from the condensation of pyrogenation water and from the initial coal hydration water, and partially from the water used for cooling the gas.

The installation must present complete operating safety.

It should not compromise the coking process.

It should require but minimum investments and operating costs.

It should enable the automation of the entire tar mass cleaning and removal process from the collector.

Owing to the particular social-sanitary and economic importance of this problem concerning removal of tar masses from the raw coke gas collectors in coal pyrogenation plants in siderurgical combines, the investigation in this country for an optimum solution of this problem constituted in recent years an important preoccupation for scientific research by our specialized institutes. Encouraging results have been obtained.

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